Fragmentation and Integration: New Evidence on the Organisational Structure of UK Firms

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Abstract

This thesis will discuss how fragmented UK firms are and how they have changed between 1997 – 2008. We examine possible explanations for fragmentation and try to capture the effects of fragmentation on employment and labour productivity. We consider an organisational and a spatial dimension of fragmentation for the manufacturing and the tradable service sector. The data used comes from the Business Structure Database — a firm and plant level database which captures 99 percent of UK economic activity.

Disclaimer

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Acronyms

ABI Annual Business Inquiry.

ACOC Annual Census of Construction.

ACOP Annual Census of Production.

AES Annual Employment Survey.

AFDI Annual Inquiry into Foreign Direct Investment.

ARD Annual Respondents Database.

ARI Annual Register Inquiry.

ASHE Annual Survey of Hours and Earnings.

BERD Business Enterprise Research and Development.

BLS Bureau of Labour Statistics.

BSD Business Structure Database.

CH Companies House.

COI Changements Organisationnels et Informatisation.

CRN Company Reference Number.

D&B Dun and Bradstreet.

DETINI Department of Enterprise, Trade and Investment Northern Ireland.

DETR Department of the Environment, Transport and the Regions.

DiD Difference-in-Differences.

FAME Financial Analysis Made Easy Database.

FDI Foreign Direct Investment.

FPM Factor Proportion Model.

FUTE Format Unifié Total d'Entreprises.

GATS General Agreement on Trade in Services.

GMM Generalised Method of Moments.

HMCE Her Majesty's Customs and Excise.

HMRC Her Majesty's Revenue and Customs.

IDBR Inter Departmental Business Register.

IIA Independence of Irrelevant Alternatives.

IR Inland Revenue.

ISS International Sourcing Statistics.

ITIS Inquiry into International Trade in Services.

IWS Industry Wage Survey.

KCM Knowledge Capital Model.

MAFF Ministry of Agriculture, Fisheries and Food.

MNE Multinational Enterprise.

NAICS North American Industry Classification System.

NSPD National Statistics Postcode Directory.

OECD Organisation for Economic Cooperation and Development.

ONS Office for National Statistics.

PAYE Pay-As-You-Earn.

SDS Secure Data Service.

SIC Standard Industrial Classification.

SNA System of National Accounting.

SOC Standard Occupational Classification.

STAN Structure Analysis Database.

VAT Value Added Tax.

VML Virtual Microdata Laboratory.

WERS Workplace Employee Relations Survey.

1. Introduction

> "*One man draws out the wire, another one straights it, a third cuts it, a fourth points it, a fifth grinds it at the top for receiving the head; ... Those ten person, therefore, could make among them upwards of forty-eight thousand pins a day ... But if they had wrought separately and independently ... they certainly could not each of them make twenty, perhaps not one pin a day ...*"
>
> Adam Smith – *The Wealth of Nations*

The main aim of this work is to provide new evidence on the structure of UK firms, and how this has changed over the period 1997 – 2008. The appearance of new organisational structures of firms has always had a large impact on societies and the development of nations (see Heilbroner, 1999). In the medieval ages until the 17$^{\text{th}}$ century typical businesses were rather small with few workers, where the workshop was often part of the worker's home. The workers were responsible for many different activities, for example, a shoemaker made a pair of shoes from raw materials to the finished product. In the early 18$^{\text{th}}$ century a period of inventions appeared, caused, amongst others, by a fundamental change of people's ideology from an after-life to a more secular orientation. Physical inventions like steam engines to run textile machines, and also new organisational entities such as companies led to dramatic changes in the structure of production. In this environment specialisation was possible. Workers sold their labour to capitalists, and specialised in a small number of specific tasks. This increased labour productivity massively. Production started to be geographically concentrated in different regions of the UK.

Until the 19$^{\text{th}}$ century typical manufacturing firms were "... predominantly organized as traditional single-unit firms ... operated in a local or regional market, produced a single line of product, and were owned and managed by a single individual or a partnership (Kim, 1999)." At the end of the 19$^{\text{th}}$ century a new kind of firm appeared, the multi-unit firm. Single-unit firms producing one output reached their limits. By setting up several plants a firm was able to experience further economies of scale and economies of scope by offering different products. Vertical linkages also gained importance. By owning the supplier of raw materials a firm could secure its input supply, and exclude competitors from this source. The main condition for the appearance of multi-unit firms was a new management structure which was able to coordinate more than one production unit. However, most of the plants of a firm were located within a country.

After the mid 20$^{\text{th}}$ century, a decline in trade barriers, an increase in capital mobility and technological developments caused the 'Death of Distance'. Transportation and communication costs were plummeting, and technological improvements changed the production process itself. Products are far more complex today than they were at the beginning of the 20$^{\text{th}}$ century. Longer production chains create more possibilities to fragment production, therefore firms started slicing up the value-added chain (Krugman, 1995). This was the ideal business environment for multi-national enterprises to arise. The whole world became a potential playing field for companies. Firms were able to concentrate production stages in those regions and countries where the required input factors were abundant. Recent OECD data shows that the total real UK outward FDI stock increased by nearly 650 percent between 1987 and 2009.[1]

FDI stocks can capture how many firms disperse their production chain over different regions, but the fragmentation of firms went even further. Firms started to outsource the production of intermediate inputs to unrelated, specialised companies. Currently, we live in a world of outsourcing. Campa and Goldberg (1997) show that for UK firms imported inputs as a share of the value of production increased in every industry between 1974 and 1993. For example, in the electrical machinery industry the share increased from 15 percent to 35 percent. Organisation for Economic Cooperation and Development (OECD) data shows that the total amount of imported intermediate goods and services

[1] See `http://stat.oecd.org`, access on 02/12/11. We use OECD deflators with base year 2008.

of the UK increased from £303bn to £340bn between 2000 and 2005.[2] These measures face some limitations because they capture international outsourcing only partly. They cannot distinguish between intra- and inter-firm trade. Also, outsourcing is not just an international phenomenon. Many small and medium sized firms hire, for example, specialised domestic cleaning companies instead of employing their own cleaning staff. Theory suggests that by focusing on its core activities, a firm can increase its efficiency, will become more competitive and therefore will experience higher profits. Several studies take account of those two aspects. For example, Abraham and Taylor (1996) show that the share of US manufacturing firms which outsourced janitorial services increased from 20 percent in 1979 to 24 percent in 1986/87.[3] Girma and Görg (2004) find that in the UK the outsourcing intensity of the electronics sector increased from around 6 percent to more than 13 percent.[4]

This thesis will focus on the last evolutionary stage of the organisational structure of firms. We present evidence to show that the organisational structure of UK firms has changed even over the relatively short period from 1997 – 2008. We examine which types of firms and industries experienced greater organisational change, and what the consequences of changing an organisational structure can be. There is already a large theoretical literature on firm organisation and fragmentation, but until recently most empirical studies about international fragmentation used aggregated data. While these can provide certain aggregated trends in fragmentation, they cannot explain the variety of organisational structures and the distribution of firm types and how they have changed over time. Firm level datasets can shed light on this. However, firm level datasets face certain limitations, for example, they might include only selected firms of certain sectors or have only information for the year, when a survey has been conducted.

[2] Real values are presented with 2005 as the base year.

[3] They find similar increases for machine maintenance, engineering and drafting, accounting and computer services.

[4] Abraham and Taylor (1996) and Girma and Görg (2004) use a different definition of outsourcing. We will discuss the differences in section 2.1.3.

In this thesis we will use the Business Structure Database (BSD), a dataset produced by the Office for National Statistics (ONS), to examine the organisational structure of UK firms. The BSD includes the great majority of all UK firms for the period 1997 – 2008.[5] The beauty of the BSD is that it includes firm level as well as plant (local unit) level information. We take advantage of this to calculate a vertical integration measure. A SIC code for each plant allows us to identify the main product produced and an eight digit postcode allows to identify its exact location. With the use of input-output tables it is possible to identify if goods produced by one plant are required as intermediate inputs in another one. A drawback of this database is that only vertical production linkages within the UK can be observed. Nevertheless, because the majority of firms do not engage in FDI, we are able to analyse how the average UK firm sources its inputs.

The following example illustrates what can be measured with the BSD. Assume a company owns two local units. One produces bricks and one is a clay pit. Because bricks require clay as intermediate input, this firm will be regarded as vertically integrated. If the firm sells the pit, it has to source the clay from the market. We will refer to this as "organisational fragmentation". If the company maintains ownership of the clay pit, we can also calculate the distance between the vertically connected plants. We will refer to this distance as a measure of "geographical fragmentation" If the bricks factory and the clay pit are next to each other, the company will be referred to as geographically concentrated. If it moves the brick factory to another region, the company will *geographically* fragment its production.

As far as we are aware, this is the first firm level analysis of the organisational and geographical fragmentation of UK firms.[6] The structure of the thesis is as follows:

Chapter 2 contains the literature review. It discusses how fragmentation is defined in the literature, what theories exist to explain different fragmentation patterns and the main

[5] At the end of 2011 new data up to 2010 was released.

[6] Note some papers from the literature review which do anything similar.

findings of the empirical literature. We will provide an overview of how fragmentation can be measured and give some reference values. In the last part of chapter 2 we will summarise the effects of fragmentation on employment and labour productivity.

Chapter 3 describes the BSD. This chapter should also serve as useful guidance for other researchers to see which questions can be answered with the BSD and what cleaning procedure is required. We will discuss the data sources and what information is included. We also provide information on *raw* data in this chapter, for example, how many manufacturing and service firms exists, what the total and average turnover in each sector is, etc. We conduct several checks to test the reliability of the BSD and compare the BSD with another large dataset of the ONS, the Annual Respondents Database (ARD). We conclude this chapter with a discussion about the usefulness of the BSD for the research on fragmentation.

Chapters 4 to 6 are the *main* chapters of the thesis. In Chapter 4 we describe the extent of organisational and geographical fragmentation in UK firms, and we show how this has changed over the sample period. At the time of writing it is the first analysis of changes in the organisational structure of UK firms over time. We examine both the manufacturing sector and what we call the tradable service sector. We start the chapter with a general overview of the UK business landscape. One main finding is that the average employment of firms, regardless of the sector, has decreased significantly during the sample period. This could be the first indicator of increased fragmentation. We then conduct a static and a dynamic analysis, discussing organisational and spatial fragmentation separately. The static analysis considers the stock of different firm types at each point in time. For example, how many multi-plant firms there are, how many vertically integrated firms, and so on. The dynamic analysis considers how the stock of different firm types evolves over time. For example, whether the change in the number of fragmented firms has arisen because of the entry of new firms or because of existing firms changing their structure. In the static analysis we show that the average degree of vertical integration is extremely low and decreasing over time. The share and degree of vertical integration is on average much lower in the tradable service sector, but once a tradable service firm is vertically integrated, it will tend to be integrated to a higher degree. According to our definition of fragmentation, only vertically integrated local units can be spatially dispersed. We find that vertically integrated firms are becoming significantly more dispersed. Again, this result is independent of the sector. A decomposition of the change reveals that the change in the average degree of organisational and spatial fragmentation is mainly caused by new firms. We conclude that the average UK firm in 2008 is more fragmented than in 1997.

Chapter 5 describes which factors can explain the organisational structure chosen by a firm. We consider regional, industry and firm characteristics and link them to common economic theories. The analysis is conducted in three stages. In the first stage we analyse the choice of a firm to be a single-plant or a multi-plant firm. In the second stage we analyse the decision to vertically integrate, and in the third stage we analyse the decision to be geographically dispersed or concentrated. In the *first* stage we do not differentiate between vertical and horizontal local units, therefore the pool of theories explaining multi-unit structures is very comprehensive. Galliano et al. (2007) and Audia et al. (2000) stress the importance of market concentration and the size of a firm. We can confirm their findings. In the *second* stage we analyse how technological variables (Acemoğlu et al., 2007), knowledge capital and incomplete contracts affect the results. While we find evidence for a similar influence of the technological variables on the choice of fragmentation, we get ambiguous results for the knowledge capital and incomplete contracts variables. Depending on the measure of knowledge capital, we find positive and negative coefficients for the probability of being vertically integrated in the manufacturing sector. We find positive, but mainly insignificant results for the tradable service sector. The third stage links the factor price differences and the knowledge capital intensity with the degree of dispersion of vertically integrated firms. Those two factors cannot explain the spatial distribution of firms. Instead we find, that large firms, which are close to the technological frontier and in a concentrated market are more dispersed. Additionally, tradable service firms in agglomerated regions are more concentrated.

Chapter 5 provides the first comprehensive analysis of common theories of organisational structure for both the UK manufacturing and tradable service sector. Changing organisational structure is a very uncommon event, but the large sample of the BSD allows us to identify a remarkable number of those events. Therefore we expect the results to be more reliable.

Finally, chapter 6 discusses the effects of fragmentation over time. To be more precise, how does the exit of a vertically integrated plant within a firm affect the employment and the productivity of that firm over time? We can follow firms up to five years after they fragmented. The total employment effect can be decomposed into a direct and indirect effect. After a firm fragments, the direct employment effect is the number of jobs lost because of the exiting plant. We expect indirect effects to arise, for example, because some jobs are moved from the exiting to the remaining plants or that, through specialisation, new jobs within the remaining plants will be created. This indirect effect may outweigh or at least mitigate the effect of the direct effect over time. If firms specialise, or if firms close down their most labour intensive plants, we also expect to observe an increase in labour productivity as a result of fragmentation. We use a Difference-in-Difference approach where we compare the performance of fragmenting firms with firms which did not fragment in the treatment year. Our results suggest that even up to five years after the treatment no positive employment effects can be observed. In contrast, employment continues to decrease in firms which fragment. In manufacturing, immediately after a firm closes a plant it will reduce total employment on average by 14 workers (-17%). After five years the absolute value increases gradually up to 18 workers (-23%). One year after a tradable service firm fragments it will reduce total employment by 5 workers (-16%), but 3 years later it will decrease by 4 workers (-13%). Large productivity gains are found for manufacturing firms. Productivity increases immediately by 27 percent and remains 15 percent higher after 5 years. Regression results suggest that productivity may even increase further over time. We do not find a clear picture for the tradable service sector.

The innovation of this chapter is that no other paper has looked at the within firm employment and labour productivity effects of the closure of a vertically integrated plant for the UK. An important caveat to the results in this chapter is that we may not be able to determine the causal effect of changes in organisational structure on employment and labour productivity, because changes in structure are endogenously determined by the firm.

We conclude this thesis with a summary about the questions we were able to answer and the limitations of the study. We will also provide an outlook of follow-up works which can be conducted.

2. Literature Review

2.1. Fragmentation and Integration

In the first part of the chapter we will derive our definition of "fragmentation" which will be used for the whole thesis. This is followed by a review about the theoretically and empirical literature of the determinants of fragmentation. We finish this part with a discussion about different ways how to measure fragmentation. In the second part we describe other determinants which can affect the organisational structure of a firm, specifically the Proximity-Concentration Trade-off. Thirdly, we look at the effects of fragmentation on employment and productivity of firms. We finish this review with a short discussion about the implications from the literature for this work.

2.1.1. What is fragmentation?

Jones and Kierzkowski were the first to use the term "fragmentation" to refer to the separation of previously vertically integrated production processes into separated fragments or blocks (Jones and Kierzkowski, 2001; Arndt and Kierzkowski, 2001). These blocks are then connected via service links, where the proximity between them is negatively correlated with coordination costs. Under the umbrella of "service links" services, like transport and telecommunication, needed to connect the fragmented production steps with other production stages, are gathered. This definition of fragmentation will be more precisely defined and a new classification introduced. We will distinguish between "*organisational*" and "*geographical*" fragmentation.

The distinction is necessary because the analysis of spatial and organisational fragmentation is influenced by different factors. For example, factor price differences between areas might affect a company to geographically separate its plants, but does not necessarily result into an organisational split up. Another reason is that empirical measures available only cover one type of fragmentation.

To examine organisational fragmentation, I will refer to Williamson (1975) who examined the boundaries of the firm. He wanted to clarify why it is the case that some activities of firms are performed within and some activities are performed between firms. To put it differently, when will a firm conduct a production stage itself, and when will it be bought from the market. If intermediate inputs are sourced from an unrelated party we will refer to this as organisational fragmentation. An organisationally fragmented firm is therefore just the opposite of a vertically integrated firm. Like Grossman and Hart (1986), pages 693*f*, I define a (vertically integrated) firm "*to consist of those assets that it owns or over which it has control*". It does not matter where the assets are located, it is only important that they are owned or controlled by the firm. Therefore, the higher the share of assets (for example machines) owned by a firm A needed to produce a product P, the higher the degree of integration will be. If most of the assets are employed by unrelated companies to manufacture P, company A is said to be highly fragmented.

At first it seems that fragmentation is just the reverse of vertical integration, but this is only half of the story. A closer look at Jones and Kierzkowski's fragmentation definition reveals that separation of a production process can also happen within a firm (see Venables, 1999 and Price, 2001). If a production process is split up, but the ownership of the assets remains, this type of fragmentation will be called "*geographical*" or "*spatial*" fragmentation. In an international framework vertical foreign direct investment falls within this classification.

Table 2.1, which is based on Price (2001), contrasts organisational with geographical fragmentation. Her table was based on international fragmentation, so I will alter it slightly to be more general. The spatial dimension informs us about the local content of a product, but does not say anything about the ownership of assets. The organisational dimension is independent from where the intermediate input producing plants are located. It shows if the production of the good is mainly determined by one management or by market forces. This table should not be looked at in a discrete context, which only differentiates between firms being fragmented and integrated. A continuous framework is more suitable, where the degree of organisational fragmentation is always between 0 and 1. 0 represents complete fragmentation and 1 complete integration. Five different outcomes are displayed. In the right top corner highly integrated companies which are highly concentrated are gathered and therefore represent the complete opposite of fragmented firms. The bottom left corner shows two dimensional fragmented firms. It could also be the case that a firm is highly vertically integrated but the firm owned plants producing intermediate inputs are widely dispersed (spatially fragmented, bottom right cell) or most of the inputs are sourced from independent local suppliers (top left cell). Another important option, which is hardly mentioned in the empirical literature, is picked up by Beladi and Mukherjee (2009) and is called bi-sourcing. It can be the case that a firm chooses to integrate a production block of an intermediate input I but also engage in a contractual relationship with other suppliers providing I simultaneously.

		Organisational dimension		
		Market		Vertical Integration
Spatial dimension	concentrated	Most inputs are sourced from local area. The coordination of the production process is guided by market forces, for example services, hospital seeking efficiency gains from outsourcing. O - -	**bi-sourcing: market & vi**	Opposite of fragmentation, one company produces most of its intermediate inputs on its own, for example farmers selling goods on-site. O - I
	dispersed	Completely fragmented company, where intermediate inputs come from all over the country and coordination is led by market, for example milk processing companies. O L -		One management is delegating local units producing different kind of goods at different locations, for example manufacturing company with headquarters in London and plants in lower costs areas. O L I

Table 2.1: Classification of fragmentation, by Price (2001), altered by author.

Finally, I want to highlight another difference to Jones and Kierzkowski's definition of fragmentation. First, they only refer to a company as being fragmented if a *previously integrated* production stage is separated from the remaining production process of the company. This assumption is not necessary, because, according to the definition discussed above, it only matters how many assets of the production process are owned by a firm (organisational fragmentation) or if the production blocks are located differently (geographical fragmentation). We define fragmentation as a state when intermediate inputs are provided by a separate unit. This separation can be caused by missing organisational linkages or geographical dispersion. According to this definition, all firms are to a certain degree fragmented because it is very unlikely that all intermediate inputs are provided within a firm. Therefore in empirical research a measure of the degree of vertical integration should be preferred to simple integration dummies.

Two expressions are often mentioned in the discussion about fragmentation, both by academics and more widely, namely "*outsourcing*" and "*offshoring*". The former is defined by the OECD as: "*Delegating (part of) activities to an outside contractor*"[7] and fits perfectly in the description of organisational fragmentation. According to OECD "..., *offshoring is used to describe a business's (or a government's) decision to replace domestically supplied service functions with imported services produced offshore*".[8] This is more related to geographical fragmentation because no distinction between ownership of the intermediate input supplier has been made. The important characteristics for offshoring are that the intermediates are sourced from a distant location abroad.

2.1.2. Why does fragmentation happen?

Many theories exist explaining geographical or organisational fragmentation and usually focus only on one of those and quite often in an international framework. A good starting

[7] See `http://stats.oecd.org/glossary/detail.asp?ID=4950`, access on 15/06/10.
[8] See `http://stats.oecd.org/glossary/detail.asp?ID=6271`, access on 15/06/10.

point is Dunning (1981)'s OLI paradigm, which is usually used to explain under which circumstances Foreign Direct Investment (FDI) come into existence, but provides also insight into fragmentation.

OLI is the abbreviation for Ownership-, Location- and Internalisation-Advantages. O-advantages arise, when companies "*possess, or gain access to, assets or rights which foreign enterprises do not possess or to which cannot gain access — at least on such favourable terms.*"[9] Typical examples for O-advantages are blueprints, intangible assets (reputation and know-how), mining rights, etc. These O-advantages are essential for a company to survive in its market or to produce at distant locations. The O-advantages are directly connected to internalisation advantages. According to Dunning, internalisation is about *"whether the enterprise possessing the assets perceive it to be in their best interests to internalise their use, or sell this right (but not the assets themselves) ...."* If a company faces I-advantages it has an incentive to keep the ownership advantage within a firm, otherwise it could offer them to other market participants through contractual agreements. An example of an Ownership and Internalisation advantage can be found in the pharmaceutical industry. Inventing new drugs is extremely knowledge capital intensive and expensive but the actual production of drugs experiences high economies of scale. To license the right of production to an outside firm bears the risk that the firm will break the contract, copies the new drug and sells it at a lower price. Therefore in countries with weak intellectual property right laws it is expected that firms are more likely to keep their ownership advantages internally.

The L-advantages comprise of those factors to which extent "*enterprises find it profitable to locate any part of their production facilities outside their home countries.*"[10] L-advantages can be factors like taxation, market potential, social factors like the acceptance of locals of foreign companies, political factors like political risk and especially

[9] See Dunning (1981), page 30.
[10] See Dunning (1981), page 30.

factor price differences.

Table 2.1 reveals which advantages have to exist so that one of the four possible outcomes can arise. An O-advantage has always to exist, because without it a company would not survive in the market. In the case of a company only facing an O-advantage, it will be organisationally fragmented but not spatially. No locational advantages exist, therefore there is no incentive to source the inputs from other locations. The company also will not be vertically integrated because of missing internalisation advantages, so it will be better off by sourcing its inputs from the market. Now an I-advantage is added. The company will be interested in vertical integration, but geographical fragmentation is still not eligible for the company because of missing L-advantages. A vertically integrated firm with dispersed plants can only arise if all three OLI advantages appear at the same time. The highest degree of fragmentation (geographical and organisational fragmentation) is achieved if only O- and L-advantages exist, so the company has an incentive to source its inputs from different areas, but, because of missing internalisation advantages, it is better off by organisational fragmentation. O- and I-advantages are linked to the firm level, but L-advantages refer to the industry or country level. This distinction is crucial because the first category is an important part for the explanation of organisational and the latter one for geographical fragmentation.[11] Two popular theories about the question of organisational fragmentation are the incomplete contract theories and the Knowledge Capital Model (KCM) and will be discussed precisely below.

Locational factors affect geographical fragmentation. One popular theory which explains the location decision for vertical production steps is the Factor-Proportion theory which concludes that, if factor price differences are big enough, a firm will consider splitting up the production process and producing at different locations. This theory is based on

[11] The differentiation between ownership and internalisation shows that ownership does not necessarily imply control over a specific good. For example, a company A owning a mine has a contractual agreement with another firm B to allow B to mine coal from A's pit. Therefore A is the owner of the mine but B is in control of it. In the theoretical literature this distinction is not always made and ownership often implies being in control.

an international framework, but note that even within a country factor prices can differ significantly (Bernard et al., 2002, 2008).

Organisational fragmentation

Knowledge-Capital Model

The Knowledge Capital Model (KCM) by Markusen (2002) is one of the most comprehensive models regarding the existence of horizontal and vertical Multinational Enterprises (MNEs). A horizontal MNE is a firm which produces the same good at home and abroad, for example, a brick producer has many plants producing the same output at different locations. A vertical MNE produces goods of different production stages of the same production process at different locations. For example, a fashion company conducts all the R&D and the creation of new designs and advertisements in the UK and produces the actual clothes in Asia. The KCM is based on Dunning's OLI paradigm. The model is named after its main reason for the existence of MNEs: knowledge capital. In contrast to domestic firms foreign firms face additional costs. To overcome those costs foreign companies need ownership advantages which may arise through knowledge capital to be competitive to local firms. Markusen assumes that knowledge capital can be easily separated from the headquarters and transferred to other production units and is non-rival in its consumption. For example, a blueprint can be used by every plant. The focus of this section lies on internalisation advantages, so to decide if a product is going to be provided within a company or sourced via arms-length transactions. If a specific knowledge capital exists which is needed for producing a certain good, it can be employed within a firm or licensed to an outside firm. However, the licensing of the knowledge capital can lead to moral hazard of the agents (licensee).

Markusen provides a model about technological knowledge to explain why in- and outsourcing can happen.[12] *Technological knowledge* is needed to produce a specific good. This good can be produced domestically in $Home$ and exported to $Host$, by foreign production, through licensing (which is equivalent to fragment the production organisationally), or FDI (vertical integration). A product has a product-cycle of two periods, after which the product becomes obsolete on the market and a new product has to be created. If a company decides to produce abroad an agent will be employed for the foreign subsidiary. She is informed about the technology used by the MNE. Moving the knowledge from Home to Host generates costs F. In the second period the agent can quit her job and use her knowledge to establish a firm on her own. On the other hand the MNE can also give notice to the agent and hire a new agent. Besides fixed costs of quitting G or training costs for new agents a penalty P has to be paid for the party who is cancelling the relationship. If the MNE wants to create a long-term relationship with the agent (that is the case of FDI) it has to give parts of the rents from producing abroad to the manager, otherwise she has an incentive for opportunistic behaviour. Licensing (fragmentation) is characterised by a single product specific relationship, so potential future income from a long-term relationship between MNE and agent over more than one product cycle is insignificant. Three outcomes can arise. If the fixed costs F are very high the MNE will service the market via exports. If G, the costs of an agent to resign from his job, is relatively high a company will prefer licensing. If it is the case that G or the penalty P for breaking the relationship are low, integration will be more likely. This is because low costs for the agent to resign from a job and low penalties for breaching the contract will result into a higher probability of opportunistic behaviour. A company can overcome this inefficiency by integration.

Even though this model is based on a horizontal framework its variables also affect vertical

[12] Markusen (2002) provides three different models based on *Reputation*, *technological knowledge* and foreign *market knowledge* to explain when insourcing or outsourcing is going to happen. All are based on horizontal motives, but only the model about technological knowledge can be extended to a vertical context.

integration decisions. For example, in the computer industry, technological knowledge is crucial for the production of intermediate inputs. The technological knowledge of required computer chips leads again to the problem of internalisation. To prevent moral hazard of a manager, integration will be preferred. All the costs mentioned above will create a similar result for vertical integration.

Incomplete contracts

Another stream of research tries to explain why companies have an incentive to engage in vertical integration through transaction costs. The transaction costs approach highlights the cost differences between integration and fragmented production. For example, according to Coase (1937) in an economy the price mechanism leads to an efficient allocation of resources and influences the behaviour of a country's individuals. But there are "islands of conscious powers" where the price mechanism is substituted by an entrepreneur who can delegate to her workers, within certain limits. Those limits are determined by contracts and finally define a firm. Coase (1937) describes why establishing a firm can be superior to a market transaction. Often it is assumed that market transactions are sufficient to coordinate and make production efficient, but there are certain costs arising. For example, it is not always possible to identify the relevant prices. If a non-standardised input is required, expert knowledge might be needed to identify the actual costs of production. Another problem is the re-negotiation of contracts for market transactions. An employee of a firm has a contract to fulfil a range of different tasks. If the economic environment is changing the principal does not have to re-negotiate the contract to have the employee to do different tasks. During an economic boom the principal does not have to write a new contract for the employee to work more hours. Also long-term contracts create some stability in an environment of uncertainty. All those factors lead to an increase in the size of a firm, which will come to an end if the advantages of integration cannot outweigh the inefficiencies of a firm becoming too large, for example through increasing bureaucracy. The transaction cost approach is a static theory, saying nothing about how the behaviour of a former unrelated manager of the intermediate input supplying firm changes if she is employed by the downstream firm. As Grossman and Hart (1986) point out, if integration leads to a reduction of transaction costs, the firm can employ strategies which makes integration always better than sourcing from the market. Why that is not the case can be explained with incomplete contracts.

Assume that two parties, a buyer and a supplier of intermediate inputs, want to trade with each other. The transaction is going to happen within two periods. In the first period (*ex-ante*) both parties decide their relationship-specific investments and in the second period (*ex-post*) further production decisions are made and the buyer and supplier will bargain about the share of profit both parties will receive after the transaction has taken place. If they cannot agree no trade will happen. With complete contracts the story would be over and an efficient market outcome would be achieved. Unfortunately complete contracts do not exist. It is impossible to include all potential scenarios within a contract. Therefore residual rights become crucial. If an unforeseen event happens the owner of the residual rights can still react to it. For example, if the owner of a construction company realises that the amount of bricks ordered is not sufficient she can, as owner of a brick factory, just increase the production. If she does not own the brick plant or the residual rights respectively, the owner (manager) of the brick factory can decide if he wants to supply more output or not. Grossman and Hart (1986) assume that in the first period no aspects of the good produced are contractible, but in the second period those characteristics are revealed and the production can be adapted. The owner of a company is also the owner of residual rights, so if the quality or quantity of intermediates produced does not fulfil the expectations of a final good producer, the company owner can react to that situation. An important point is that the ownership structure affects the profit distribution, and therefore affects the relationship specific investments of the first period. Exactly those ex-ante investment distortions create an inefficient outcome, which a firm can minimise by choosing the right organisational form.

Grossman and Hart (1986) compare the efficient outcomes of perfect contracts with the outcomes of imperfect contracts and integration and non-integration decisions of companies. They conclude that if an upstream company does not care about non-contractibles (for example the quality of an intermediate good) it is better for the downstream firm to own the intermediate input supplier. The reason is the following: Ownership leads to a higher degree of power ex-post, therefore a company has an incentive to over-invest in the first period. If non-integration has been chosen the investment level will be moderate for both firms. So if ex-ante investments are crucial for company A, but not for firm B non-integration can lead to under-investment and therefore not to an efficient outcome.[13] To summarise, incomplete contracts can lead to distorted investment decisions in the first period. This under-investment problem is a hold-up problem (Tirole, 1988). An intermediate input supplier can choose how much she wants to invest to specialise its intermediates. The upstream firm will under-invest because an efficient amount of specialisation might create the fear that if the trade fails, it will be more difficult to sell the goods to other market participants and all the investments are forgone.

Grossman and Helpman (2002) employ incomplete contracts to illustrate the choice of a company to integrate or outsource the production of intermediate inputs. Three kinds of firms exist, where one is completely vertically integrated, one only assembles the final product and the last only produces intermediate inputs. In comparison to an integrated firm, outsourcing is characterised by a more efficient production and therefore lower costs but also confronted with search costs of a supplier to find a final good producer and vice versa, and a hold-up problem through incomplete contracts. The incomplete contract will lead again to a lower output and a higher price than with a complete contract. If

[13] The idea of ex-ante contracts needs further explanation. Someone could assume that in theory a breach of contract can be penalised by a third party (for example a court). In reality it can be impossible to specify all the details within a contract and it could be impossible for a court to tell if, for example, the quality of the intermediate input meets its standards.

a partner cannot be found, the firm will exit the market. These cost differences arising through the organisational form require a different level of industry demand to let a firm break even. As all firms are similar, industry characteristics decide which organisational form will be prevailing.[14] One result is that it is extremely unlikely that in one industry vertical integration and outsourcing is prevailing simultaneously. Furthermore, five factors will influence the probability of an industry having integrated or specialised firms (final and component producers) only. Some are rather obvious, for example the higher the *production costs advantages* of specialised component producers are and the lower the *fixed costs* for final and component producers are, the higher will be the propensity of having an outsourcing equilibrium in that particular industry. An improvement in the *search technology*, so it is easier for specialised firms to find a complementary firm, will increase the expected profits of those firms and also has a positive effect on outsourcing. More complex is the effect of the *substitutability of final goods*. A high degree of substitutability is similar to a highly competitive market. If the cost disadvantages of outsourcing through search costs and incomplete contracts are lower than the costs arising through dis-economies of scales through vertical integration, then a higher degree of competition leads to more firms engaging in fragmenting the production. Another channel affects the number of specialised component suppliers. In an industry with similar goods the advantage of specialisation is diminishing, therefore the number of specialised intermediate input suppliers will decrease. This will increase the probability of an intermediate input supplier to find a matching partner and decrease the market demand needed to break even and will boost outsourcing. Finally, the *bargaining share* of the surplus from selling the final good is influential. Firstly, the higher the bargaining power of the component supplier, the higher is the expected profit and the easier it is to break even. Secondly, a larger share of the surplus leads to a disincentive of the intermediate input supplier to under-invest because of incomplete contracts. Thirdly, higher expected

[14]For example, if the industry demand to have zero expected profits is higher for a vertical integrated firm than for a fragmented firm within an industry, the latter can produce at a lower price.

profits lead to an increase in the number of entering component firms which decreases the matching probability with final good producers and affects the required market demand negatively.

Acemoğlu et al. (2010) offer a theoretical model heavily based on Grossman and Hart (1986). Again, two kinds of market participants are considered, a risk neutral supplier and producer. Those firms can be independent, or integrated, where the supplier can own the producer (*forward integrated*) or the producer can own the supplier (*backward integrated*). As in Grossman and Hart (1986) ownership leads to an increase in investments. Investments can only flow into plants owned by the firm; in other words, the producer cannot conduct investments for the supplier. Acemoğlu et al. (2010) show why investment incentives differ depending on the organisational form. They put their focus on outside options of firms, meaning how much a firm will receive if the supplier cannot provide the good ordered or the producer declines to accept it. The outside option depends on the organisational form. For example, if the contract between a backward vertically integrated producer and the integrated supplier is cancelled ex-post, then the supplier will have an outside option of zero, because the producer is the owner of the residual rights and owns all the assets. The supplier will leave with nothing. The producer can still use the produced intermediate inputs, but her output will decrease. This is caused by not using the appropriate intermediate inputs. The higher the outside option of a firm the higher will be the share of revenue they will receive for sure. This leads to a decrease of revenue for the other firm in the contractual agreement. The higher the revenues, the higher the investments will be, but while the firm with the higher revenues will invest more, the other firm is confronted with less revenue and will invest less. Three factors determine which organisational form will be the best outcome. First, technology matters. The more technology intensive a firm is the likelier it is to be vertically integrated.[15]

[15] Acemoğlu et al. (2010) use in their model a parameter indicating the relative importance of investment. They interpret it like the more important the investment of a firm is, the more value added it brings and the better technology the firm uses.

The next factor is the importance of the input of the supplier for the final good of the producer. For example, an engine producer is the supplier and the car producer is the final good producer. The engine is crucial for a car, so not supplying the engine would be devastating for the car producer. To ensure that the engine is delivered, backward integration will be likely to happen. Finally, a larger number of producers relative to suppliers will lead to an increase of non-integrated firms. Because a supplier can more easily find a producer he can sell his products, the outside option will increase for the supplier.

Antràs and Helpman (2004) combine the incomplete contract theory with the Melitz model of heterogeneous firms.[16] The main concept is that firms differ in their productivity, which will be decided by a random draw at the beginning period. The least productive firms will exit the market, the more productive firms will service the domestic market and the most productive firms will be exporters.[17] Antràs and Helpman (2004) also add a fragmentation dimension to the model. Two countries, called North and South, are given, where the wages in North are always higher than the wages in South and labour is the only primary input. The assembling of the final good always happens in the North, the production of the headquarters services like R&D likewise and of the intermediate component in both countries. The production of the intermediate inputs can be outsourced to another supplier. Regarding the costs the crucial assumption is that the highest fixed costs are related to vertical integration abroad (in the South) and the lowest to outsourcing at home (the North). The outside option of firms depends on the organisational form. On the one hand, a final good producer engaged in outsourcing will have an outside option of zero if there is a breach in the contract. On the other hand, vertically integrated firms can, even if negotiations fail because the quantity/quality supplied by the supplier is not what the buyer has expected, still fire the manager of the

[16]See Melitz (2003).

[17]Head and Ries (2003) get the same result with a much simpler model.

intermediate input supplying affiliate and use the intermediate inputs produced. The final outcome would be lower than if the negotiations had not failed. The expected share of revenue will therefore be higher for integrated firms, but the supplier will produce less components. This setting leads to the following main results: Only the most productive firms will be vertically integrated, less productive firms have to exit the market or engage in outsourcing. Besides firm characteristics, industry characteristics are crucial for the organisational dimension. Antràs and Helpman (2004) show that only in headquarters service intensive sectors fragmentation will happen, in component intensive sectors outsourcing will be prevailing. The reason for this is that incomplete contracts lead to an underinvestment in the component and in the headquarters service production. The higher the bargaining share is the lower will be the underinvestment. A profit maximising firm will prefer outsourcing to insourcing if the final good is component intensive and integration if it is headquarters service intensive because the relevant profit share is closer to the profit maximising bargaining share.

On first appearances technological differences are closely related to the KCM. While in the latter model the main reason for integration is moral hazard behaviour of agents, using already existing knowledge capital for their own advantage, the technological difference approach deals with what organisational form should be applied so a new technology can be implemented efficiently. To be more specific, Acemoğlu et al. (2007) examine when it will be more likely for a firm to shift the decision making process to managers and when will it be better off by keeping the power concentrated. Their model works as follows: A company can decide how a new technology should be implemented. If it is implemented correctly the firm will experience a productivity growth. If it chooses the wrong way, nothing will happen and the company remains at the same productivity level. Two systems are considered: concentration or delegation of power. If the first one is chosen, the principal will be solely responsible for deciding how a new technology will be implemented. Her decision will be based on the history of other companies' actions (which are available to the public). If nothing is known about the correct way of implementation, it is difficult for the principal to make the right decision. If the power of decision has been delegated to a manager, the manager will always know the correct way to implement a new technology. Unfortunately it is not always the case that the manager's decisions are congruent to the principal's decisions. The manager gets a private benefit if his preferred choice has been chosen, even if that means that the right technology will not be employed. According to Aghion and Tirole (1997) reasons for that could be less effort to implement it, better future career opportunities, etc. Now a trade-off arises. Through assumptions it is the case that, on the one hand, it is more likely for the principal and the manager to follow the same aims. This means the owner will accept the manager's advice. At the first look it will always be better for a company to delegate power to a manager. Another assumption states that if there is sufficient information about the reference action available, the probability of a principal choosing the right action will be higher than the manager and the principal having the same opinion. This creates the trade-off. Acemoğlu et al. (2007) assume that an increase (decrease) in technological heterogeneity (homogeneity) will lead to an increase in the degree of decentralisation within a firm. The more (less) homogeneous (heterogeneous) the firms are, the more information can be gained by other firms that have been implementing the new technology already. If a firm is producing at the technological frontier, then delegation will be the preferred structure, because no public information is available how to implement new technologies. Therefore it is more likely that delegation leads to a better outcome. This theory is based on firm internal decisions[18], but how it will be applied for fragmentation can be found on page 154.

[18]Aghion and Tirole (1997) focus on the differences between real and formal authority within a firm, and show that real authority can deviate from formal authority. We only have information at the formal authority level.

Geographical fragmentation

In addition to the decision of the organisational structure a company also has to choose where the intermediate inputs should be sourced from.

Factor-Proportion models

Factor Proportion Models (FPMs) can explain why a company splits up its production and establish plants at different locations, even if that leads to unused economies of scale. The reasons are factor price differences between countries (or regions). The analysis by Helpman (1984), and Helpman and Krugman (1985), is based on the Heckscher-Ohlin model of international trade, but the capital intensive or manufacturing sector is extended. It is assumed that the home country is relatively capital and the host country relatively labour abundant and no transport costs exist. Three factors are needed for the production of final manufacturing products: Labour L, capital K and a general purpose input factor H.[19] H, headquarters services, are intangible assets of a company, which can be transferred easily to other plants in different countries, for example, management and product specific R&D. Capital and labour cannot move between countries. Because of large factor price differences no factor price equalisation can arise through trade. If the differences are large enough it can be worth for a company of the home country to specialise the production of headquarters services in the home country and shift the labour intensive production stages into the host country. This can lead to factor price equalisation, but not necessarily.

Even though the FPM are presented in an international framework it can also be considered for national fragmentation decisions. Even within countries factor prices differences can matter. A comparison between Nottinghamshire and Inner London reveals that median hourly paid wage of all full time workers is £11.86 for the former and £16.55 in

[19]Note that in Helpman (1984) capital K was neglected.

the latter in 2009.[20] Big differences may exist in property prices. To set up a factory in London is much more expensive than in the Midlands. The headquarters can still be located in London, but the production facilities will be moved to other regions. An empirical testing of factor price differences between administrative regions and post code areas was conducted by Bernard et al. (2002) for the UK for the years 1986 and 1992. They show that for six out of ten regions the factor price equalisation hypothesis can be rejected. More disaggregated geographical data leads to a similar result. One main assumption of the model is that workers can move from one industry to another but no migration between countries is assumed, because otherwise factor price equalisation can be achieved even without fragmentation.

Venables (1999) offers a model which is more general than Helpman's model because it does introduce trade barriers. Again there are two countries, the capital abundant home country and the labour abundant foreign country. The production of a manufacturing good requires intermediate inputs, which on their own require capital and labour. The intermediate good can only be transferred within a company. While the final good can be traded freely, the intermediate goods are confronted with a tariff. Of course, the tariffs will only arise in an international context. In a national framework tariffs may be substituted by the costs of service linkages, which will be explained in the next paragraph. If the tariff is too high, no fragmentation will happen. Now suppose that the tariff is reduced. If it is assumed that the final assembly is more capital intensive than the production of intermediate inputs then the production of the intermediates will be move abroad. Vertical FDI arise, where the intermediate input is exported back to the home country. If the upstream production process is more capital intensive than the downstream production process, the home country will specialise in intermediate inputs and the final assembling will happen at home and abroad, because the export of

[20]See online "Official Labour Market Statistics" of the Office for National Statistics (ONS) at `http://www.nomisweb.co.uk`, access on 11/01/10.

intermediates on its own is facing trade costs. Horizontal FDI will arise.

Jones and Kierzkowski (2001), focus their analysis on factor cost differences and the cost of service linkages. Service linkages comprise of telecommunication, transport, etc., to connect fragmented production stage with each other. They show with a two factor model that a country can improve its welfare by changing from an integrated to a fragmented scenario. Two intermediate inputs with different factor intensities are needed to assemble a final good. They compare the situation of a totally integrated production and the production of a final good, where the intermediate inputs are traded on the world market, with a decathlon athlete.[21] If an athlete is only good at one contest and horrible at others she will not be able to win the competition. A sportswoman who is average at all contests is likely to win. If you add up the result of only the best athletes of all contests, the final result would be superior to the "integrated" results. Fragmentation causes increased fixed costs which arise because of the service linkages, but, through increasing returns to scale of services, the variable marginal costs will be lower for fragmented than for integrated firms. They conclude that small companies will tend to be integrated, medium sized companies to be nationally fragmented and large companies will engage in international fragmentation.

Services in the manufacturing sector are theoretically discussed in a paper by Van Long et al. (2005) who focus on the link between fragmentation and services. The idea of the paper is based Jones and Kierzkowski (2001). According to Jones and Kierzkowski services are needed for fragmentation to happen, if services are facing increasing returns to scale. Van Long et al. (2005) stick to this approach. Two countries exist, where one is characterised by lower wages (the host country, for example India) and a more developed country offering more specialised services (the home country, for example the United Kingdom). Labour is the only primary input factor. The production of a manufacturing

[21] Of course, this example depends on the form of the production function. A function which requires some minimum level of all inputs would have this property. But other functions would not have this property.

good requires components as an input factor. Components on their own need what are called "aggregated services". The idea behind aggregated services is the following: A country can produce a certain amount of different specialised services. Services consist of R&D, accounting, transport, telecommunication, infrastructure, etc. Aggregated services arise through the combination of specialised services, where the higher the amount of different specialised services used will lead to a decrease in the production costs of the final good. The bigger the country is, the more of those specialised services it can offer. The authors distinguish between non-tradable and tradable services. If services are non-tradable the result will be that service intensive components will be exported by UK, labour intensive components will be exported by India. UK is appreciating a positive home market effect. Furthermore, if India is going to increase its variety of specialised services the range of goods exported will also increase. In the second scenario tradable services are introduced. If no transport costs exist the home market effect will disappear. The price for the aggregate services will be the same then for all countries. Therefore the production of components will happen in the country with lower wages.

The Knowledge-Capital Model

The very comprehensive KCM by Markusen (2002) is not only able to describe when internalisation occurs, but also when geographical fragmentation will happen. The KCM can explain the existence of companies being only domestically active, of horizontal and of vertical MNEs. We will focus on vertical MNEs.

There are two countries, two homogeneous goods and two input factors (unskilled labour and skilled labour). These factors are able to move freely between industries but cannot be shifted to other countries. Also transport costs exist. The manufacturing good is produced with increasing returns to scale at the firm and at the plant level. Vertical and domestic firms can service foreign markets via exports. *Fragmentation costs* are low and *jointness* is high.[22] Fixed costs depend on which strategy is chosen. All of those assumptions lead to the result that the choice of strategy depends on the market size of both countries, the fixed costs of the strategy chosen and on the price mark-ups, which also depend on transport costs.

If both countries are of similar size and factor prices are quite similar then only horizontal MNEs will exist. If the factor prices are diverging from each other than a mixed strategy with national and multinational firms will arise. The more the factor prices differ from each other, the higher is the possibility of the appearance of vertical firms.[23] Given trade costs, elasticity of substitution, low fragmentation costs and high jointness, the strategy chosen depends solely on the differences in factor endowments. The KCM shows that geographical fragmentation depends on factor price differences and furthermore if transport costs are too high, then no vertical integration will happen. But those conditions are not sufficient to have geographical fragmentation to arise. It also depends on the market size and which country is relatively skilled labour abundant.[24]

Markusen modifies the model by allowing a fragmented production process where one block of it is producing physical intermediate inputs which are needed to assemble a final good. Factor price differences are still important but, unlike before, too large differences have a negative effect on vertical fragmentation. The market size affects the decision of vertical fragmentation. If the host country is small in comparison to the home country a proportionally larger amount of goods has to be exported back to the home country,

[22] See page 15 for the definition of fragmentation costs and jointness.

[23] Under certain circumstances, large differences in factor endowments and size of the countries, a domestic exporting firm equilibrium can exist.

[24] If one country A is large and the other one called B is quite small, the final production stage will happen in A, mainly because the proximity to the final market reduces costs. The decision of where the headquarters are located will constitute then if a company is internationally fragmented or not. If the small country B is skilled labour abundant, and the factor costs of skilled labour are significantly different, then companies will locate their headquarters in B. If the large country is well endowed with skilled labour, then the optimal strategy is concentration in the large country. But even if both countries have the same size, but one country C is skilled labour abundant in comparison to country D, vertical integration can still come into existence if the price differences between the final good prices are high enough. Then companies might skim the rents in D by setting up a local production in D and keeping the headquarters in C.

which leads to an increase in transport costs.

Summary

Organisational and geographical fragmentation require different explanations, where the former one is dependent on internalisation advantages and the latter one on locational advantages. Organisational fragmentation can be explained by two streams of literature. The KCM focuses on opportunistic behaviour of agents which arise through the existence of knowledge-capital. This leads to internalisation (integration) being preferred to licensing (fragmentation). The second stream deals with incomplete contracts. Because perfect contracts do not exist, the decision of generating the second best outcome out of the contractual relationship through external or internal sourcing depends on how important specific intermediate input factors are for the production of the final good. Geographical fragmentation can be explained by the KCM as well as with the Factor Proportion models. Both lead to the same result that factor price differences matter.

2.1.3. Empirical evidence on the determinants of fragmentation

Many studies have been conducted to find determinants of the organisational structure of firms, but often the theoretical differentiation between the organisational and spatial dimension has not been accounted for. A second drawback of the empirical literature is that often only a multi-plant structure is considered without taking account of whether those plants are vertically integrated or not. This empirical literature review will start with summarising aggregated studies from the 1970s and will lead to recent firm level studies.

Early studies were mainly based on cross-section data but, over time, time-series data became available. The majority of studies are based on aggregate FDI data. Those FDI flows are actually financial flows and might lead to an under- or overestimation of the real activity of a company abroad.[25] An often quoted study about the causes of FDI is by Caves (1974). This study was already published before Dunning introduced his OLI classification. Caves used data from the manufacturing sector of Canada and the UK to conduct two separate cross industry studies by taking average values for the variables between the years 1965 – 1968. The dependent variable used is the share of sales accounted for by foreign owned firms. The independent variables are categorised into three different groups called *intangible capital*, *multi-plant enterprises* and *entrepreneurial resources.* The first one comprises assets which are necessary to be able to compete with local firms which already possess knowledge of the local market. These assets must be assets which can be used in the foreign market without losing its functionality. The multi-plant enterprise factors consist of all advantages having multiple firms in relation to a concentrated production. Low economies of scale at the plant level and transport costs would be part of this category. Finally, if a company possesses excessive entrepreneurial resources it can use them abroad, for example, if it has unused resources of skilled workers, those can be employed abroad to use full production capacities. Because higher profits are expected in sectors where higher entrepreneurial skills are required MNEs will predominantly be located in those sectors.[26] In all regressions the intangible assets variable were significant and had the expected positive impact. The multiple plant variable is significant and positive for Canada but insignificant for the UK. The entrepreneurial resources factors lack on empirical evidence. Caves must confess that even the theoretical foundation is rather weak. This model gives already insight into how many factors can influence FDI decisions.

With increasing worldwide FDI flows in the 1980s, the determinants of FDI attracted

[25] See Riegler (2007) for a precise explanation of how FDI are measured and what the actually include.

[26] A lot of those arguments were included in theoretical models decades after this paper. For example, the intangible assets which can be easily transferred to foreign countries and excessive entrepreneurial resources like headquarters services are an important part of the Helpman (1984)-model. Brainard (1993), formalises the trade-off between trade costs and economies of scale at the plant level in the Proximity-Concentration trade-off model.

more and more attention of the scientific world. After the OLI-paradigm by Dunning (1981) was published, researchers tried to classify determinants of FDI according to this scheme.[27] As an example an article by Pugel (1981) will be discussed. Pugel uses US industry average data for the period 1967 – 1970. He includes intangible assets which can be easily transferred to foreign subsidiaries in his study. He divides these O-advantages into proprietary technology, marketing and promotional activities and organisational and managerial techniques. All these factors can be summed up as headquarters services. Another O-advantage is the ability of established MNE to get access to favourable funding sources. L-factors affect the choice of exporting vs. outward FDI. For Pugel factors like transport costs and economies of scale are part of this category, which favours centralizing or decentralising of production. Another argument, already used by Caves (1974), is that MNEs will usually be located in oligopolistic markets, because it is easier for them to surpass existing entry barriers. These barriers lead to a high concentration of companies. Therefore a positive relation between FDI and concentration is expected. Finally a positive relationship between FDI and firm size is assumed. The bigger the firm the easier it is to raise capital and are better suited for engaging in international production. He finds evidence for a significant positive impact of ownership advantages. Economies of scale at the plant level have a significant negative impact on FDI but distance measured as transport radius is not significant.

From the 1980s onwards, many studies about FDI have been focused on locational advantages which is the important factor for spatial fragmentation. One area of concern was tax rates. One early paper is by Hartman (1984) who saw tax rates as the main reason for FDI and did not account for any other covariates. Hartman used time-series data, had few observations and the data quality is questionable. He pointed out that direct investors respond to effective and not to statutory tax rates. Slemrod (1989) explains

[27] See Dunning (1985), for an overview about different case studies about determinants and effects of FDI.

that Hartman's view is too narrow and highlighted the importance of inclusion of other independent variables. He shows the shortcomings of Hartman's approach and estimated his own model using an effective marginal tax measure, and also takes non-tax variables which might influence the flows of FDI into account, like, for example, the real exchange rate, a measure of relative size of the US to the investing countries and a measure for capturing business cycle effects. Slemrod's result, contrary to Hartman's, is that taxes have a negative impact on total FDI and transfers of funds but not on reinvested earnings.

The estimation methods and the theoretical foundations improved a lot over time. The famous gravity model of Newton, which became popular in economics for estimating trade flows between countries, also became a crucial part of the FDI literature. The main idea is that the larger two masses (countries), and the lower the distance between those masses is, the higher the amount of trade-flows between those countries will be. The effect of distance on FDI is ambiguous. Proximity means there are less cultural barriers and therefore it is easier to set up a business in close markets. If potential markets are rather far away then high transport costs can make it worthwhile to do FDI.[28] An augmented gravity model using panel data is very common nowadays for studies looking at aggregated FDI flows.

For example, Bénassy-Quéré et al. (2005) and Bellak and Leibrecht (2009) using panel data and the gravity model to look closer at the effects of taxes on FDI flows.[29] Both find a negative impact of taxation and in, general, significant effects of gravity variables. Surprisingly, the Bénassy-Quéré et al. (2005) measure of relative unit labour costs is positive, meaning that the higher the unit labour costs the more inward FDI will be

[28]The gravity model with FDI suffered from the same problem as trade flows — the lack of theoretical foundation. The popular theoretical justification of gravity models for trade flows is based on Anderson and van Wincoop (2003). With some delay a framework was also found for FDI models. The application of the gravity model for FDI flows was theoretically justified by Kleinert and Toubal (2005). They derive the gravity model based on the FDI theories mentioned in 2.1.2.

[29]See Devereux (2006) for an explanation which tax rate should be used for FDI decisions and de Mooij and Ederveen (1999) for a meta study about the impact of taxes on FDI.

attracted.[30] Distance is insignificant, which is interpreted as a proof for the proximity concentration trade-off. Bellak and Leibrecht (2009) mention that the importance of taxation should not be overrated because other determinants have an equal or even greater impact, for example, the higher the unit labour costs in the host countries are the lower will be the amount of FDI flows into those regions. Razin and Sadka (2007) estimate a gravity model but differently to above their focus was not on taxes but on different estimation methods. Data used comes from 24 OECD countries from 1981 to 1998. Using a gravity model can lead to a large loss of data, because zero and negative values are omitted through the logarithmic calculus. Additionally, fixed costs can prevent companies to invest abroad. A two stage Heckman model can take account of these factors.[31] Their results can differ strongly based on the estimation method. The coefficient for distance is significantly negative. The cultural distance measured by a common language dummy is positive and significant. The size variables are with the exception of the selection stage of the Heckman model significant, the same applies for GDP per capita in the host and the home country. Görg et al. (2007) look at the effect of the interaction between taxes and social expenditures on inward FDI flows of OECD countries. Their main result was that the overall impact of taxation (social expenditure) is softened by social expenditures (taxation). Furthermore, market size attracts FDI, but unit labour costs and capital costs are positive but insignificant.

The international literature proves that ownership advantages are necessary to become a MNE. A company needs some knowledge capital to be able to compete in different markets, but also that sourcing from the market would be less profitable. The choice of where a company will locate its plants will be then based on locational factors, like unit labour costs. Still, to be able to look at the effect of certain factors on organisational or spatial fragmentation, more precise data is necessary. For example, for organisational

[30] They explain it with the Balassa Samuelson effect.

[31] Other models estimated are a model where zero values of FDI inflows are substituted with the smallest amount of FDI flow prevailing in the data, a model where all zeros are omitted and a Tobit model.

fragmentation it is more important to have data about how many inputs of a firm are sourced from the market.

At the end of the last century there was an increase in papers discussing this topic. Most of those papers are based on firm level data, but nearly every paper uses a different concept for measuring fragmentation. Abraham and Taylor (1996) is one of the most cited papers in this area. They are using US manufacturing data from the manufacturing Industry Wage Survey (IWS) for the year 1979, 1983 and 1986/87 and do not differentiate between foreign and domestic outsourcing. Only firms with at least 20 to 100 employees can be part of the survey. Five different services are considered: janitorial services, machine maintenance services, engineering and drafting services, accounting services and computer services. Firms have to report what share of those services has been outsourced to outside contractors. In the regression a sample between 1,500 and 2,000 observations is used. Three different categories of determinants are considered. The first ones are *cost-savings advantages*. High wages and high benefits, because of strong trade unions, provide an incentive for outsourcing to reduce costs. The second argument is based on *volatility of output demand*. It can be better for firms to hire outside suppliers during peak time to satisfy demand instead of producing everything internally and having unused capacities during off-peak periods. Finally, there is an argument of the availability of *specialised skills* possessed by outside suppliers. Examples are complex computer problems which can be better dealt with outside IT experts. Specialised services are also connected to regional aspects. The more concentrated a region is the more specialised service provider will be available and therefore the likelihood of outsourcing should increase. The model estimated is a ordered Probit model because the dependent variable is divided into six different categories.[32] They add industry dummies to take account of unobserved industry effects. The main results are that cost-savings advantages are the main reason to

[32]The categories are 0%, 1% – 25%, 26% – 74%, 75% – 99%, 100% and outsourcing has happened but the percentage is unknown.

outsource low skilled janitorial services. The effect of trade unions is not clear. With the exception of janitorial services, larger firms are more likely to contract out the other four services. Finally, a metropolitan region has a positive significant impact on outsourcing for accounting and computer services.

A paper dealing with the determinants of fragmentation in the UK is by Girma and Görg (2004). They use firm level data of the Annual Respondents Database (ARD)[33] for three different manufacturing sectors, chemicals, mechanical and instrument engineering and electronics for the period 1980 – 1992. Firms with more than 100 employees and some smaller firms are included. They define outsourcing as *"cost of industrial services received by an establishment"*. Therefore non-industrial services like accounting, janitorial services etc., which were part of the Abraham and Taylor (1996) definition, are not included. Besides Abraham and Taylor's determinants they put a special focus on foreign ownership. They expect foreign owned firms to be more likely to be fragmented. Being part of a MNE means that firms will be more specialised by definition, they can easier find outside contractors and because of being expected to use better technology than domestic firms, more likely to outsource low-skilled activities. The number of observations varies between 5,700 and 23,600 depending on the sector and estimation method. OLS and first difference regressions with using lagged outsourcing as explanatory variable are used. The latter regression can take care of time invariant unobserved firm heterogeneity and the correlation between outsourcing now and in the past periods. Both models show a positive effect of foreign ownership on outsourcing activities. The level analysis also finds evidence that high wages are positively correlated with outsourcing.

Tomiura (2005) provides evidence for Japan. He uses cross-sectional firm level data for the year 1998. The data captures the whole Japanese manufacturing sector and does not have any firm size restrictions. The beauty of the data is that a differentiation between foreign and domestic outsourcing is possible. Outsourcing is defined as *"the yen value*

[33]This database will be discussed on section 3.6.

outsourced to firms located overseas and that to firms located inside the country, respectively." Firms outsourcing non-production overhead services or arm's length purchases of standardised goods are not included. Finally contracting out to own subsidiaries is not differentiated from outsourcing. Therefore the actual organisational fragmentation can be overstated. This paper shows different characteristics of firms which are or are not foreign and/or domestically outsourcing. Tomiura (2005) focuses on technological differences between firms, namely productivity, computer usage, physical capital per labour ratio and R&D intensity. Additionally, firm size effects are taken into account. Descriptive statistics show that firms which are outsourcing overseas (offshoring) are generally much bigger, more productive and require a higher amount of human skills. In the empirical model the correlation between technology and foreign outsourcing intensity measured by value of outsourcing divided by sales is tested. Because of the large number of firms without any foreign outsourcing activities Tomiura (2005) employs a two-stage Heckman selection model.[34] His results are that there are significant fixed costs for entry, more productive firms and firms using more computers are more likely to outsource. The capital to labour ratio has a negative correlation with foreign outsourcing. Finally R&D is an important determinant for domestic and foreign outsourcing.

A recent study by Díaz-Mora (2008) deals with the Spanish manufacturing sector for the period 1993 – 2002. In contrast to the three studies mentioned above, industry level data for 93 industries is used. Outsourcing is defined as parts of the production process carried out by other firms. Again, the range of activities included in this concept is rather limited and contains only product related tasks. The determinants are similar to Girma and Görg (2004) but she adds an export propensity indicator. It is expected that exporting firms have a better international network and can therefore find a specialised supplier more

[34] This model deals with the problem of censored data. For example, it could be the case that a firm would engage in foreign outsourcing but, because of certain fixed costs, it will not be able. Therefore the selection of firms actually engaging in foreign outsourcing is not exogenous any more (Razin and Sadka, 2007, ch. 7). The Heckman model deals with this selectivity bias.

easily. This paper estimates a dynamic model by using a Generalised Method of Moments (GMM) estimator and at least three lagged variables for endogenous variables. Her main result is that outsourcing is persistent, because of high costs of setting up an outsourcing relationship. Again, there is evidence that high unit labour costs increase the probability to outsource. Interestingly, she finds that a higher share of domestic firms leads to a higher outsourcing level, which is in contrast to the result of Girma and Görg (2004). Furthermore, in industries with high skilled requirements more outsourcing will appear.

Another stream of literature focuses on locational factors like, for example, geographical concentration, as determinants of fragmentation. Already Abraham and Taylor (1996) used a regional concentration measure to indicate the amount of specialised services offered. Taymaz and Kiliçaslan (2005) look at how regional development affected outsourcing in Turkey. They have firm level data for the textile and engineering sector for the period 1993 – 2000. Only firms with at least 10 employees are part of the sample. A random effect Tobit model with two different dependent variables is estimated. Subcontracting intensity is measured as share of subcontracted inputs and as the share of subcontracted outputs but those inputs or outputs are not specifically defined. To show the importance of networks and clusters they use the number of firms in the same industry and the same province and expect a positive relation with subcontracting. Many firm characteristics are controlled for like average wage, firm size, capital intensity and the share of skilled workers. Taymaz and Kiliçaslan (2005) find significant evidence that geographical concentration has a positive effect on outsourcing in the textile and engineering industry. The effect of capital intensity on the share of subcontracted inputs is positive in both sectors.

Holl (2008) links sub-contracting decisions with the location of Spanish firms of the manufacturing sector for the period 1990 – 1999. Only firms with more than ten employees are considered. For the final estimations more than 16,000 observations exist. Like Taymaz and Kiliçaslan (2005), Holl expects agglomeration to have a positive influence on outsourcing. First, search costs for finding a suitable subcontracting partner are lower. Second, through tougher competition between providers, prices for intermediaries will go down. Finally, proximity to upstream and downstream industry will lead to time-savings and lower transportation costs, which supports subcontracting. Outsourcing is defined as a *"contractual relationship in which the firm commissions a third party company to produce products, parts, or components made to the firms specification."* Arm's length trade is not included. The variable of interest, agglomeration, is measured as the total regional industrial employment density. Other firm characteristics controls are wage costs, size, age and foreign ownership. Holl highlights simultaneity issues, for example, it could be the case that more productive firms are active in agglomerated regions and that also more productive firms are more fragmented, which could lead to an overestimation of the effect of agglomeration on outsourcing. To take account of the correlation of the error term and the covariates, a Chamberlain random effects model is employed. The results are that agglomeration has a positive impact on subcontracting decisions. Also age, wage and size have a positive impact on the probability to outsource.

Acemoğlu et al. (2010) test the property rights theory of Grossman and Hart (1986) for UK firms.[35] To be more precise, they differentiate between how the technological intensity of the final good producer and intermediate inputs supplier affect the decision to be vertically integrated. They expect that if the producer is technology intensive, then firm i will be integrated, if the supplier is technology intensive, than firm i will be fragmented.[36] Acemoğlu et al. (2010) use a vertical integration dummy and a continuous vertical integration measure which uses input-output tables to link together plants within firms.[37] The unit of observation is the firm industry pair level, for example how much of an specific intermediate input required to produce a good are produced by a firm. If the good requires three intermediate inputs than three observation of that firm will

[35]See page 17 for a description of incomplete contract theories.
[36]See pages 21 for the theoretical background of the paper.
[37]We use a similar measure in this thesis. See page 49 for a detailed explanation.

exist. R&D intensity is measured by R&D expenditures divided by value added at the industry level. The databases used for the vertical integration measures are the ARD and input-output tables, and for the R&D intensities the Business Enterprise Research and Development (BERD) database, all provided by the ONS. Acemoğlu et al. (2010) use a linear probability model for the vertical integration dummy (rather than a binary model), because it is easier to interpret, easier to estimate if the sample is large and individual fixed effects can be used to control for unobserved firm effects. The cross section sample consists of nearly 3m observations. The results confirm the theoretical model, regardless of whether the dummy or the continuous measure are used.

In contrast to the papers mentioned above, Acemoğlu et al. (2007) are interested in whether the decision-making power of a firm is concentrated or delegated to managers. They test how the distance to the technological frontier, technological industry heterogeneity and age affects the power delegation. The dependent variable is a dummy indicating if a firm has the decision power delegated to affiliates, which can act as profit centres autonomously or it is concentrated and affiliates are just cost centres with much less autonomy. The main analysis is based on French data from Changements Organisationnels et Informatisation (COI) merged with Format Unifié Total d'Entreprises (FUTE) files and leaves a cross section file with 3,570 observations, where all independent variables are lagged. Because of a dichotomous dependent variable a Probit model with industry dummies was estimated and all results are in accordance with the theory. Firms closer to the technological frontier, firms active in a technological heterogeneous environment and younger firms are more likely to delegate power. Many different robustness checks have been conducted to address specifically the endogeneity topic. As instrument for French industry characteristics British industry data sourced from the Annual Business Inquiry (ABI) is employed. The IV-Probit supports the baseline results. Furthermore, the model with French data is also estimated for the UK by using the Workplace Employee Relations Survey (WERS), but was facing several limitations, for example, many covariates are not available for British firms. Still, also this analysis supports their theory.

The empirical literature about spatial fragmentation is less evolved and often based on anecdotal evidence. Chandler (1990) offers a descriptive analysis about how firms have changed over time. He describes through his observations what kind of firms will be geographically dispersed. First, firms have to reach a certain size, so they can make use of their economies of scale and scope. After reaching a certain level, firms start to set up plants in different locations. Most arguments are based on horizontal local units, like increasing market size and product diversification. The vertical argument is mainly based on defensive reasons. A company wants to secure the flow of inputs (for example from mines) if they are not available in the local area. Audia et al. (2000) find evidence to support Chandler's claims. They are interested in how the organisational structure of a dispersed firm will affect the performance of the firm. Evidence is found that geographically dispersed firms perform better than concentrated firms. They focus their study on US manufacturers from 1949 – 1989. Data comes from the Annual Shoemaking Directory of Shoe Manufacturers. Their explanation is that dispersed firms benefit from lower transport costs and risk diversification, which is similar to Chandler's results. In contrast to the often stated assumption that knowledge can be easily transferred between local units, Audia et al. (2000) find evidence that after reaching a certain distance knowledge can be hardly transferred any more and also the usefulness of knowledge is declining.[38] But as will be shown in the following studies, geographical dispersion is based on more factors than just risk diversification.

That risk diversification is not the only factor for spatial dispersion show Landier et al. (2009). They find evidence for the link between spatial dispersion of a firm and the tendency of managers towards employees and shareholders. It is easier for a firm to lay-off workers and sell-off of local units which are further away. They argue that social

[38]They measure this effect by interacting an experience variable based on Ingram and Baum (1997) with geographical dispersion and find that dispersed firms benefit less from operating experience.

pressure of the local community will influence managers. This social pressure seems to be much stronger in smaller villages than in big cities, where the employee protection seems to be absent. Concluding, a firm can choose to be spatially dispersed to conduct a more shareholder than employee friendly policy. Data comes from a variety of sources, for example financial information is provided by Compustat, employee information comes from SOCRATES, division data from Hewitt Associates and divestiture data from Secure Data Corporation (SDC).

A study which looks at the determinants of spatial fragmentation is by Galliano et al. (2007). They use a two stage Heckman model. In the first stage they estimate which firms will be more likely to become multi-plant firms. In the second stage they focus on the spatial fragmentation of the local units. The determinants tested are firm internal characteristics like firm size, economies of scale and economies of scope, and firm environment factors, for example, in which area the headquarters are located. It is assumed that if the headquarters are located in urban areas then firms will be more likely to be multi-plant and geographically dispersed firms. This argument is related to the factor-price difference argument, where production stages will be moved to less populated areas to decrease the costs of production, but keeping the headquarters in cities because of the higher number of skilled people and a bigger variety of services offered. The beauty of the study is that the authors were able to differentiate between horizontal and vertical multi-plant firms. The authors use French data from the Annual Survey of Firms (ASF) of 2001 which consists of around 22,000 observations. They find strong evidence of firms' size having a positive effect on the probability of becoming a multi-plant firm and being dispersed and a negative effect of economies of scale at the plant level. Many firm characteristics have similar effects on the dispersion of horizontal and vertical local units. The main differences are that investment in ICT matter for the degree of dispersion of vertical local units. Higher ICT expenditures are positively correlated with vertical dispersion.

Firms with headquarters in cities and local units in peri-urban[39] areas have the spatial profile for being most spatially dispersed.

Another related stream of literature focuses on the location decision of production and service stages of companies. Strauss-Kahn and Vives (2009) discuss headquarters location and relocation decision of firms. Headquarters are likely to be found in regions with concentrated business services, same industry specialisation and agglomeration of other headquarters. Henderson and Ono (2008) add another dimension to the Strauss-Kahn and Vives (2009) analysis. They look at how important the distance between production local units and first stand-alone headquarters are. They find that the location of the headquarters depends on the distance to the production facilities. This result is supported by Defever (2010). His analysis is focused on the location decision of production and service activities of multi-national firms in Europe. He finds that firms mainly reinvest into the same regions. Proximity to existing production plants matters for the location of new production facilities, however this does not seem to be of importance for service activities.

There is not always a clear separation of organisational and spatial fragmentation in the empirical literature. The literature focusing purely on organisational fragmentation is more comprehensive than the literature about spatial fragmentation. The results for the former are sometimes ambiguous, which is often related with different kind of variables employed to capture outsourcing. Papers about international fragmentation show that factor price differences matter for spatial fragmentation. Additionally, agglomeration effects seem to influence the spatial dimension of a firm.

[39]Areas which are between the suburbs and the countryside.

2.1.4. How can fragmentation be measured?

While it is the case that the theory behind fragmentation has been very elaborately investigated, the literature of how to measure fragmentation has still to catch up. An improvement in the availability of data leads to an enhancement of the quality and precision of the measurement. There is no unique measure for fragmentation because of its complexity mentioned in table 2.1. To be able to provide a precise measure for organisational and spatial fragmentation, we will present them separately.

Organisational fragmentation

The pioneer of measuring vertical integration was Adelman (1955), and since then there have been further developments to improve that measure. The measures used in the literature can be classified in different ways. One way is according to the aggregation level, for example, the degree of vertical integration at the economy, industry, firm and local unit (establishment) level. Furthermore, vertical integration can be conducted in different direction. A company can be forward or backward vertically integrated. A downstream firm which buys a supplier would become backward-integrated. An upstream firm[40] which buys a firm which it supplies would become forward-integrated. Some empirical measures distinguish between these two cases, and some do not. Finally a classification into classical and input-output tables based measures of vertical integration helps to give a clearer picture of how the degree of vertical integration can be calculated. Table 2.2 overviews existing measures of vertical integration. Vertical integration is just the opposite of organisational fragmentation and can be calculated by one minus the degree of vertical integration. The reader should be reminded that this way of calculation is only suitable for creating a measure of organisational fragmentation and does not capture

[40] Antràs et al. (2012) created recently a measure for the distance of an industry to the final customer ("upstreamness"). For example, car producers deliver in general straight to the final customers, but products of firms in the petrochemical industry will pass several stages before they reach the final customer.

information about geographical fragmentation.

	Classical		
	Backward	Forward	no diff.
Local Unit	—	—	—
Firm	Adelman (1955), Gort (1962), Tucker and Wilder (1977)	Adelman (1955), Tucker and Wilder (1977)	—
Industry	Adelman (1955), Tucker and Wilder (1977)	Adelman (1955), Tucker and Wilder (1977)	—
	Modern		
Local Unit	measure used in this thesis	measure used in this thesis	—
Firm	Acemoğlu et al. (2010), measure used in this thesis	measure used in this thesis	Maddigan (1981), Davies and Morris (1995)
Industry	Davies and Morris (1995)	Caves and Bradburd (1988), Davies and Morris (1995)	—

Table 2.2: Vertical integration measures used in literature

Classical measures of vertical integration

As mentioned above, Adelman (1955) is regarded as the starting point of measuring integration. He presents a "value-added to sales" measure at the economy and the firm level. The latter, which is also used by Tucker and Wilder (1977), looks like

$$vi_k^{adel} = \frac{V_k}{S_k} \tag{2.1}$$

where V_k is the value-added by firm k and S_k the sales of firm k. If a firm is completely vertically integrated, then the value added is equal to sales and vi_k^{adel} equals unity, for example a self-sufficient farmer who produces everything by using his own intermediate inputs. Outsourcing leads to a constant amount of sales but a decreasing amount of value added, therefore the measure will decrease. The firm measure is criticised, because it strongly depends on where the firm is located in a production chain. The closer the firm produces to a primary sector the more likely it will be having a high degree of vertical integration (Adelman, 1955; Tucker and Wilder, 1977; Maddigan, 1981; Caves and Bradburd, 1988; Davies and Morris, 1995).[41] Note that, according to Adelman, the industry classifications of firms depend on the industry of the final good producer. For example, an iron ore extracting company which is producing intermediates for the car industry is part of the same industry as the actual final car assembler. The value added to sales ratio will be lower for the car assembler than for the iron ore producer. It is therefore difficult to compare the degree of vertical integration of firms in the same production chain. If we only consider the industry of a firm and not of the final product, this problem will not arise. The Adelman (1955) measure can also be calculated at the industry level and can avoid the problems mentioned.[42]

Gort (1962) identifies which production steps are separable and which are not. Only if it can be observed that, within an industry, some firms exist which source goods from a vertical production stage externally, then those firms who source them in-house will be regarded as integrated. To solve this problem a 4-digit SIC code is used. Gort (1962) got information about products produced from public records. The more SIC activities, which are needed to produce the final good, a firm performs, the higher will be the degree of vertical integration. The final good or the “main” activity is identified by the highest employment share which can be allocated to an activity. The rest are regarded as “auxiliary” activities. Employment data was gained through Census of Manufacturing. To gain the degree of vertical integration Gort (1962) calculated the number of people

[41] Adelman (1955) illustrates the problem with the following example: Imagine three firms in a given industry exist where a company A is a primary production firm, B a manufacturing firm and C a retail firm. All of them are responsible for a value added of five currency units. vi_k^{adel} will be one for A, 0.5 for B and 0.33 for C. If B acquires A, than its degree of vertical integration will increase to one (out of B's sales of ten currency units, all value added is generated internally). If forward integration happens (B buys C) then the vi_k^{adel} will only be 0.67 (Five units of value added are still produced by unaffiliated company A). Forward and backward integration lead to a different result and forward integration can even lead to a decrease in the degree of vertical integration, if the downstream firm is sourcing the majority of intermediate inputs from other firms.

[42] Eckard (1979) and Davies and Morris (1995) further point out that many datasets only allow to generate an intra-industry firm measure, and not an inter industry measure.

employed in auxiliary activities in relationship to the number of people employed in total by the firm. It looks like as follows and is a measure for the firm level.

$$vi_k^{gort} = \frac{L_k^{aux}}{L_k^{tot}} \tag{2.2}$$

Again this measure is confronted with certain problems. The selection of main and auxiliary activities is sometimes arbitrary, the data collection can be very laborious and the interpretation of data often requires expert knowledge (Davies and Morris, 1995).

Input-output measures of vertical integration

The new generation of vertical integration measures is based on an idea by Maddigan (1981), where all of those new measures use information of input-output tables. Maddigan focuses on the firm level.

$$vi_k^{madd} = 1 - \left[\frac{1}{\prod_{i=1}^{n}(C_i)^T(C_i)(D^i)^T(D^i)}\right] \tag{2.3}$$

where T stands for transpose and n for the number of industries firm k is part of. C_i and D^i need further explanations. C_i (D_i) represents the i^{th} column (row) of firm k's input (output) matrix. Those matrices are generated through input-output tables. So to get C_{ij} someone has to calculate the share of net-output of industry j caused by intermediate inputs from industry i. Then only those industries are selected in which firm k is active. D_{ij} is calculated similarly with the exception that the share of industry i's net-output delivered to industry j is used. A numerical example in the appendix on page 264 can help to improve the understanding for that measure. Davies and Morris (1995) point out that this measure treats all firms with the same distribution of local units over the industries equally, regardless the amount of the local units' output.

Caves and Bradburd (1988) create a forward oriented measure of vertical integration for industry i, where the size of the activities of firms belonging to industry i in industry j are considered. They use the share of intermediate inputs of industry i delivered to industry j of the IO-tables to identify the vertical connection between each sectors. Then the number of firms are counted which are located in sector i and j and the share is then used as a weight, see the following equation.

$$vif_i^{C\&B} = \sum_j b_{ij} \left(\frac{NV_{ij}}{N_{ij}} \right) \tag{2.4}$$

where b_{ij} is the share of output from industry i delivered to industry j, weighted by the share of companies from industry i which are also active in industry j, divided by the total number of firms in industry i or j, depending on where the smaller number of firms exist. Unfortunately this measure only provides information at the industry level.

Davies and Morris (1995) circumvent the problems of the two measures mentioned above. Three different measures are presented, a firm level measure of vertical integration with no distinction between forward and backward integration and a forward and backward measure at the industry level. Similarly to above, relative shares from use or supply matrices are used and weighted then by the market share of each company, instead of the relative share of the number of firms Caves and Bradburd (1988) are using.

$$vi_k^{D\&M} = \sum_{i=1}^{R} \sum_{j \neq i}^{R} b_{ij} \frac{X_i m_{ij}^k}{X^k} \tag{2.5}$$

$$vif_i^{D\&M} = \sum_{j \neq i}^{R} \sum_{k=1}^{N} b_{ij} m_{ij}^k \tag{2.6}$$

$$vib_i^{D\&M} = \sum_{j \neq i}^{R} \sum_{k=1}^{N} a_{ji} m_{ij}^k \tag{2.7}$$

where N is the number of firms, R the number of industries, a_{ji} is the technical coefficient, b_{ij} the sales destination coefficient and m_{ij}^k a market share coefficient.[43] The measure

[43] m_{ij}^k represents the minimum of the market share either in industry i or industry j.

for forward integration of industry i aggregates the share of output of industry i sold in industry j weighted by the firms market share. The same procedure is used for the backward integration measure, where instead of b_{ij} the share of goods from industry i demanded by industry j is used. Finally the firm level measure of equation 2.5 identifies all intra-firm flows and divides it by firm k's total sales.[44] No differentiation between backward and forward vertical integration is made.

Two strong assumptions are considered: On the one hand, fixed technical and sales destination coefficient are assumed, meaning that all firms of the same industry have the identical input and the same customer structure. While the assumption of a Leontief technology where all firms use the same technology seems reasonable, the assumption of the same customer structure seems rather far-fetched. On the other hand, it is further assumed that internal transactions are always preferred to arms-length trade. So if a firm has a local unit in an intermediate good supplying industry it will source the good from its affiliate and not from other firms. We will use similar assumptions for our vertical integration measure in this thesis. Those assumptions have advantages but also face certain limitations. We will discuss this further in section 4.4.1 on pages 114*ff*.

Finally, Acemoğlu et al. (2010) generate a dummy variable and a continuous variable for vertical integration. In contrast to above the measure is less aggregated and displays the degree of vertical integration of firm k for an industry pair ij. They focus on backward integration but the measure could also be used for forward integration. The dummy is created by looking if a firm has a local unit in a sector which is an intermediate input supplier for one of firm k's products:

$$vid^{ace}_{kij} = \begin{cases} 0 & \ldots \text{ if firm } k \text{ does not own a plant in industry } j \text{ supplying industry } i \\ 1 & \ldots \text{ if the firm } k \text{ owns at least one plant in industry } j \text{ supplying industry } i \end{cases} \tag{2.8}$$

[44] It does not matter if a_{ji} or b_{ij} is used.

The continuous measure at the firm level requires more information. The demand of firm k for intermediate input j for its output of good i is calculated by total costs of firm k to produce output i and the technical coefficient. For the vertical integration ratio this value is used as the denominator and the amount of firm k's production of j as numerator. This is formally presented in equation 2.9. For example, a firm k is producing footballs, which is product i. One intermediate input j is leather. The total costs c_{ki} of footballs are 10, the technology coefficient derived from the input-output tables shows that 50 percent of intermediate inputs come from the leather industry, therefore the whole demand for leather of company k is 5. If the firm produces leather worth of 5 internally (x_{kj}), then the firm will be vertically integrated to 100 percent.

$$vib_{kij}^{ace} = \min\left\{\frac{x_{kj}}{c_{ki}a_{ij}}, 1\right\} \tag{2.9}$$

The measure is different from the other measures. While all measures have been focused on the industry, firm or local unit level, this one is a *within* firm measure. For example, for a firm A producing bricks many different vertical integration measures can be derived. One could be about how much clay needed for the production is mined by company A. Another one might be about how much saw dust is provided firm internally. Because both measures, the dummy and the continuous, look only at the pair-wise connection of supplying and demanding industries for every firm, it is not aggregated enough to give information about the degree of integration at firm level.[45] The problem of the dummy is obvious, no differentiation between the degree of integration can be made. The advantage is that it is easy to calculate. The continuous measure is more accurate but more data is needed.

Summary of measures of vertical integration

A broad range of measures of vertical integration has been offered in the empirical liter-

[45]It would be possible to aggregate the industry pairs to a firm level measure though.

ature. They can be broadly classified in classic and input-output tables based measures where the latter use information from input-output tables to identify the technology structure or sales structure of firms or industries. Examples of classical measures are value added to sales ratios or the size of auxiliary activities to main activities. The main drawback of those measures is their sensitivity to the position of a firm in a production chain or the difficulty to gain information needed to identify auxiliary and main activities.

The input-output tables based measures have to deal with the problem of strict assumptions regarding the technology or sales distribution of firms. For example, firms in the same industry are using the same technology, if firms are producing intermediate inputs, then those intermediate inputs will be sufficient to satisfy the firm's demand. Therefore bi-sourcing cannot happen. Only the major activity of a plant can be measured. If a firm produces different intermediate inputs in the same plant, then the vertical integration link may not be captured. However, although there are certain limitations we will use this measure, because we can generate it for every firm in our sample, it requires little information and the measure is straightforward to interpret.

Geographical fragmentation

An obvious measure of geographical dispersion is by looking at aggregated FDI data. An increase in outward FDI means that domestic companies are conducting more activities abroad. This measure has several drawbacks. First aggregated FDI data is very crude, it does not differentiate between vertical and horizontal FDI, can be a camouflaged portfolio investment, and (maybe the most important point) does not capture domestic dispersion. The majority of firms is not acting at an international level. Therefore by ignoring the domestic dispersion of firms the actual degree of dispersion will be strongly undervalued by FDI figures. Additionally, aggregated data can disguise the actual level of dispersion of an average firm. Therefore other firm level measures of dispersion are needed.

An easily derived measure is a multi-location dummy which is 1 if a firm has local units in more than one region. Landier et al. (2009) use a same or adjacent region dummy instead. This dummy is 1 if divisions are in the same or in an adjacent region of the headquarters. This measure does not take account if a firm has local units in two or in all regions of a country. To improve this situation Landier et al. also create a continuous measure. They use longitudes and latitudes of cities to measure the spherical distance between headquarters and its divisions.[46]

Audia et al. (2000) use a similar continuous measure. They calculate a spherical distance between all local unit pairs (dyads) within a firm by using information on longitudes and latitudes of cities where the plants are located. Then the Logarithm is taken and a within firm measure is calculated.

Galliano et al. (2007) use a different approach by calculating a multi-location intensity measure. This intensity is derived by looking at the employment share of a firm in different regions. By applying equation 2.10 a value of one implies that all firms are within the some region. The bigger the multi-location intensity gets the more dispersed the firm is.

$$ML\ intensity = 10^E \text{ with } E = \sum_r A_r \log\left(\frac{1}{A_r}\right) \tag{2.10}$$

A_r represents the share of employment of a firm in region r

2.1.5. Empirical evidence

Most studies are focused on vertically integrated multi-plant firms[47], because most data is available for those firms to measure the degree of organisational and geographical fragmentation. Furthermore, it is much easier to allocate different production blocks to a specific company than if the intermediate inputs are supplied by an unaffiliated company.

[46] Because only information exists, in which states the divisions are located, Landier et al. (2009) use the most populated area as measurement point for the distance between local units and headquarters. They admit that this measure is rather noisy.

[47] This would be the right bottom cell in table 2.1

The degree of organisational fragmentation is calculated at the national level in a couple of studies. Geographical fragmentation is mainly dealt with in an international context, where no differentiation between the sourcing from affiliated and unaffiliated companies is made.

Organisational Fragmentation

All the measures presented in this section are calculating the degree of vertical integration at the firm level. The measures presented cannot be compared with each other directly, but it is still possible to look at the trend or degree of vertical integration. Not many studies exist applying classical vertical integration measures at the firm level for empirical analysis. The main problems are data restrictions and limitations of its explanatory power. For example, Adelman (1955) ends up with a firm sample of 183 large companies to calculate his value added to sales ratio. The measure is just calculated for the year 1949 and, because of a lack of comparable estimates, nothing can be said about whether the overall degree of vertical integration of a company is high or low. Tucker and Wilder (1977) create a time series of value added to sales ratios using data for the period 1953 – 1973, but again, only 54 companies sourced from the COMPUSTAT database are included in the analysis. They conclude that there was hardly any change in the degree of vertical integration within those 20 years. It is questionable how representative the result is because of its very low number of observations and inclusion of large firms only.

The input-output measures of vertical integration might have specific advantages regarding to the traditional measures, but one severe problem could not have been solved at the beginning of the 80s: the small number of observations. Maddigan (1981) used US input-output tables for 1947, 1958, 1963, 1967 and 1972 and Moody's Industrial Manual to identify the industries a company is part of. 96 US firms which incorporated before 1947 were randomly chosen from the COMPUSTAT database and then analysed. The degree of vertical integration can fluctuate a lot over time (for example if a company sells one of its affiliates) and across firms. Maddigan finds that the mean of the degree of vertical integration of firms is significantly increasing over time. 96 companies are a rather small sample to explain the change of average degree of vertical integration of US firms and Maddigan on his own confesses that the "random" selection is not actually random, because only firms are considered which were incorporated before 1947 and reappeared then in the sample for the next 25 years.

Davies and Morris (1995) use input-output tables from 1985 and create a market share database, which is based on individual company reports and information from the UK census. The latter one contains information about the market share of the five largest companies within one of the 97 industries of the input-output tables. With 306 firms left only a fraction of the whole manufacturing population can be covered. Nevertheless they find some interesting results. Half of the large companies included are completely fragmented (have a vertical integration measure equal to zero), and even if a company is integrated, the degree is rather low. The most highly-integrated firm sources only 8.3 percent internally, and the mean value of integration within integrated firms is only about 1.38 percent.

Acemoğlu et al. (2010) use a more detailed measure, namely the degree of vertical integration of the backward link between industries i and j of firm k. The ARD is used to gain information of total costs of a company and how much of an input it is producing. The input-output table of 1995 delivers the share of total of a specific input. Their sample consists of 2,973,008 observations on 46,392 firms. The sample is aggregated for the period 1996 – 2001. They reveal that the degree of vertical integration of an industry pair of a company is with an average of 0.008 very low, but a high deviation can be observed. Those variations do not only appear across but also within industry pairs.

Geographical Fragmentation

Geographical fragmentation is predominantly a topic in international economics. An often cited paper by Krugman (1995) explains the increase in "slicing up the value chain" of production, meaning that the complexity of goods is increasing which creates more possibilities of production stages being separately conducted. It is becoming more common to have different production stages generating only a small amount of value added. Feenstra (1998) gives support to international fragmentation. He discusses how offshoring affects today's international trade flows. Offshoring is measured by the share of imported intermediated inputs to domestic intermediate inputs. No differentiation is made between international outsourcing and sourcing through affiliates abroad. The results he presents from other studies are that offshoring has become more important. For example, the ratio of imported to domestic intermediate inputs increased for US manufacturing firms from 5.7 percent (1972) up to 13.9 percent (1990) (based on Feenstra and Hanson, 1997) and also the results of Campa and Goldberg (1997) are similar with increasing ratios for Canada, the US and the UK, only for Japan a counterfactual trend is observed.

There are several problems with these studies. Firstly, those studies only differentiate between domestic production and outsourcing abroad. So if geographical fragmentation should happen within a country, those measures would not take account of that. Secondly, no information is given where the intermediate inputs come from. It is a difference if the geographical fragmentation happens in the same or in a distant region (for example within the European Union or in Asia). Thirdly, it is unknown if the extensive and/or intensive margin of firms engaging in spatial fragmentation has increased.

2.2. Crucial Determinants for Other Organisational Structures

So far we have mainly been concerned with the vertical relationship between different production stages. But another dimension has not been discussed yet. As we will show below in the empirical part of the thesis, many multi-plant firms exist without any vertical linkages. One important reason for that is the proximity to final markets, which was theoretically discussed and put into a formal framework by Brainard (1993).

2.2.1. The Proximity-Concentration Trade-Off

Brainard (1993), uses a two sector, two country model and a similar framework like Helpman (1984). In contrast to Helpman (1984) a company can still have an incentive in becoming a multi-plant firm even if factor price equalisation does happen. The crucial factors in this model are firm level economies of scale, plant level economies of scale and transport costs, which were assumed to be zero in the Factor-Proportion Model. Firm level economies of scale arise through headquarters services, so that the more a company spends on R&D, the lower will be the production costs in every plant. The generated knowledge can be used in every subsidiary without diminishing value.

The proximity-concentration trade-off exists because, on the one hand, a company can benefit from economies of scale at the plant level if the production is concentrated in one or just a few locations. On the other hand, proximity to the target market reduces transport costs. Additionally, if economies of scale at the firm level are high, then production costs will be decreasing for every plant and therefore setting up another local unit will be more likely.

To be more precise, a firm confronted with high fixed costs at the plant level faces a lower propensity to become a multi-plant firm. Setting up another car factory can be very expensive, therefore, for example, Toyota does not have production facilities in every European country. In contrast, headquarters service intensive industries will be characterised by a higher number of multi-plant firms. The costs for producing headquarters services can be spread among all affiliates without a loss in value. Transport costs are increasing in distance, this would mean that the further the target market is away, the more likely it will be for a firm to have several plants.

Empirical international studies show that intra industry trade is a very important part of total trade and MNEs are responsible for a significant part of trade.[48] To take account of these facts Brainard improved the model by introducing a three stage production in a differentiated good sector. Additionally to the R&D and the manufacturing production stage, sales activities are included. The input factors for the sales stage is the output from the manufacturing stage. An increase in the amount of inputs will decrease the variable costs of selling. This is similar to the relationship between R&D and the manufacturing process with the difference that R&D can be spread amongst all affiliates and inputs from the manufacturing sector just for one sales affiliate. If the sales facility is near the manufacturing unit then no transport cost will arise, but if they are in different locations the firm will face additional transport costs. A firm has to check if the fixed costs through establishing an affiliate abroad can be outweighed by the decrease in variable transport costs. The extension of the model shows that the proximity-concentration trade-off model can explain why MNEs are responsible for a significant amount of total and intra industry trade.

2.3. The Effects of the Organisational Structure on the Performance of Firms

The last bit left is to find out how fragmentation affects the performance of firms. Especially, we examine the effects of outsourcing on employment and productivity. The most closely related literature is the international outsourcing and offshoring literature.

2.3.1. Employment effects of fragmentation

A good overview of the definition of offshoring, measurement issues, theoretical foundation and empirical evidence on the effects of offshoring on the employment level of the developed and developing countries is provided by Bottini et al. (2007). The predictions

[48] See Brainard (1993), page 24.

of the theoretical literature are ambiguous. One stream of literature sees offshoring as a way to increase labour supply. If foreign workers are perfect substitutes for domestic workers, then the domestic unemployment rate will increase. This fear is normally associated with unskilled workers. Blinder (2006) mentions that also high skilled jobs are at risked of being moved to foreign countries, as services are getting more and more tradable. The positive effects of outsourcing can come from efficiency gains which then reduce unemployment rates. A firm can become more competitive in the world market and therefore can increase its exports. Furthermore, the fragmentation of production can also lead to an increase in the demand for headquarters jobs to co-ordinate and supervise.

One important contribution is by Feenstra (2004), who set up a simple theoretical model which can explain how the implementation of intermediate inputs can change the sectoral relative labour demand between skilled and unskilled workers causing increasing relative wages for skilled workers. This model was also empirically tested by Feenstra and Hanson (1996). They find evidence that 31 – 51 percent of the increase in relative demand for skilled labour can be related to outsourcing.

Greenaway et al. (1999) empirically assess the impact of trade on UK employment, where trade also includes trade in intermediate inputs. The main result is that trade has an impact on employment, the higher the trade volume is the lower will be the labour demanded. However, trade is an imprecise proxy for outsourcing and therefore any conclusions may be adventurous. Falk and Wolfmayr (2005) look at how outsourcing to regions with different labour endowments is affecting the employment of EU countries. They use two digit manufacturing industry data for seven EU countries. If only imports from low wage countries are considered, then an increase in imports of intermediates will have a negative effect on industry employment. Outsourcing to industrialised countries does not have any impact on employment.

One shortcoming of aggregate studies is that most theories are based on a micro foundation, for example, how will offshoring change the behaviour of a firm. Therefore channels through which an increase in offshoring is affecting aggregated employment, might not be revealed. A solution is to use firm level data.[49] In general the empirical literature follows two approaches: First, some studies compare the employment growth of firms which started to outsource with firms which did not. One paper following this approach is by Biscourp and Kramarz (2007). They use French firm level data to analyse the effects of importing intermediate inputs and final goods on the employment level of manufacturing firms. The data consists of 330,000 observations, if only continuing firms are kept, the sample still has around 150,000 firms. They find evidence that an increase in imports per firm will reduce the firms employment rate. This effect is even worse if goods produced are final and not intermediates. They compare the rates of employment growth between 1986 – 1992 of firms with distinctive characteristics, like new-born firms, dying firms, continuing firms which have been further classified into firms which have never imported, started importing, stopped importing or continuously imported. In this part just raw changes have been compared and other explanatory variables have not been taken into account. Therefore Biscourp and Kramarz (2007) conduct also a first difference regression for all continuing firms.

Another paper using a similar approach is by Hijzen et al. (2011). The authors focus on the effect of importing (offshoring) of producer *services* on the labour employed at UK firms of the manufacturing *and* financial and business services sector for the period 1996 – 2004. They use two firm level datasets of the ONS, the ABI and the Inquiry into International Trade in Services (ITIS). Like Biscourp and Kramarz (2007) they start their analysis with a similar descriptive approach and conduct a slightly modified first difference regression. Additionally to standard regressions Hijzen et al. (2011) conduct a quantile regression analysis and propensity score matching. The results are different to the outcome predicted by Biscourp and Kramarz (2007): There is no evidence that

[49]On the other hand, firm level data might miss out the bigger effects.

offshoring of services leads to a decrease in employment. Firms which start offshoring are experiencing an even higher employment growth than firms which have never imported services.

Ando and Kimura (2007) conduct a similar analysis for Japanese firms for the Period 1998 – 2003. The authors focus on offshoring of Japanese manufacturing and service firms in East-Asia. They found evidence that offshoring does have a significant positive effect on a company's decision not to reduce employment. They find different results for non-manufacturing firms. If a firm is increasing the amount of offshoring abroad it leads to growth rates of employment of 3 – 8 percentage points higher than of other manufacturing firms. Again, for non-manufacturing firms those results cannot be observed.

The main reason for a positive employment effect are according to Hijzen et al. (2009) that vertical FDI lead to efficiency gains to withstand competitive pressures in manufacturing and therefore experience a higher employment growth. Ando and Kimura (2007) conclude that at least for manufacturing domestic and foreign production processes are complements rather than substitutes. Another could be that the increased demand for outsourced inputs coincides with a positive (unobserved) demand shock, which would question the causality of above's results.

The second way to deal with the problem is by using a quasi-experimental technique. One group of firms is experiencing a treatment, for example, firms start outsourcing. The change of the variable of interest is then compared with the change of the same variable of the untreated group. This can be done by propensity score matching (Hijzen et al., 2011, 2009) or by using a Difference-in-Differences (DiD) estimator (Hijzen et al., 2010). Hijzen et al. (2010) look at how mass lay-offs or plant closures affect the earning of a displaced workers in the following five years. UK data of one percent of UK employees for the period 1994 – 2003 is used. Even though this paper does not directly touch the question of the firm employment effects after the closure of a plant, the empirical strategy used in this paper will be one of the main foundation chapter 6. Their main result is that after a plant closure workers are confronted with earnings 20 – 34 percent lower over the following five years. They highlight that the results are very sensitive to the chosen control group. Besides implementing a DiD estimator they also use propensity score matching techniques. Hijzen et al. (2009) follow this approach and analyse the effects of internationalisation of a firm on the performance of the firm or, more precisely, on the domestic employment, skill-intensity, productivity and exports. French data-sets are used, which include manufacturing firms with more than 20 and service firms with more than 30 employees for the period 1984 – 2002. The authors are differentiating between manufacturing and service sectors and horizontal and vertical FDI. They find that FDI of the service sector and horizontal FDI of manufacturing firms into a high income countries and industries, where the firm has a comparative advantage in, have a significant positive impact on domestic employment in comparison to firms which did not internationalise. Even for vertical FDI of manufacturing firms no evidence for job losses for the parent firms was found.

Finally a completely different approach is taken by Görg and Hanley (2005). They look at the effects of outsourcing on the labour demand on the plant level. This study is focused on the short-run and on the Irish electronics sector. The data comes from the *Irish Economy Expenditure Survey*. They use a GMM technique for estimation, because they include lagged dependent variables on the right hands side to introduce adjustment costs in their model.[50] The result is that an increase in outsourcing leads to a decrease of the plant level employment. The measure of outsourcing consists of imported intermediate inputs. This outsourcing measure is calculated at the industry level, so, to be more precise, an increase in the propensity of an industry to outsource leads to a decrease of the plant level employment. Concluding, there is mixed empirical evidence about the effects of offshoring on employment.

[50]Standard panel data estimators would lead to biased results in a dynamic model.

2.3.2. Productivity effects of fragmentation

An excellent overview of the empirical literature about the effects of fragmentation on productivity is provided by Olsen (2006). He separates studies into studies at the industry and at the firm level and also presents studies providing indirect evidence. The empirical evidence for the effect of outsourcing on productivity is not as straight forward as expected.

Two often cited studies at the industry level are by Fixler and Siegel (1999) and ten Raa and Wolff (2001). The former analyse whether outsourcing of services of manufacturing firms affects the labour productivity of the manufacturing and service sector. If manufacturing firms outsource services and source them cheaper from the market, then their output per labour will increase. The effect in the service sector can be ambiguous. Fixler and Siegel expect positive effects on the service sector productivity only in the long-run, when demand for external services of manufacturing firms stabilises and service firms can adjust their production function. US industry data (450 manufacturing and 57 service industries) from 1959 – 1990 was used and divided into three sub-periods. Productivity is measured as output per worker. They find empirical evidence for their expected results. ten Raa and Wolff (2001) analyse what caused the increase in TFP in the manufacturing sector in the 1980s and 1990s after years of productivity stagnation. They suggest that manufacturing firms could boost their productivity by outsourcing services. The data used for analysis comes from US input-output tables for six years within the period 1947 – 1996, which allows us to decompose the TFP growth into growth caused by a change in productivity of manufacturing and of service firms. Ten Raa and Wolff conclude that the manufacturing productivity increase is related with outsourcing.

For a more detailed analysis firm level data is required. An early firm level study is by Görzig and Stephan (2002). Return on sales and return per employee are the dependent performance variables of the estimated model. Different types of outsourcing activities are measured: the change in (a) material inputs to capture material outsourcing, (b) external contract work to capture subcontracting and (c) costs not related to production to capture service outsourcing. A panel data with 43,000 manufacturing firms between 1992 – 2000 is used. To capture long-run effects they use a between-firm and to capture the short-run effects a within-firm estimator. In the long-run all types of outsourcing have a positive effect on the return per employee, but in the short-run outsourcing of services decreases profitability. The authors conclude that in the short-run firm may overestimate the benefits of outsourcing and therefore and outsource above an optimal level.

Girma and Görg (2004) use the ARD to estimate the effect of outsourcing intensity on labour productivity and TFP for the chemical, the electronics and the engineering sector. To mitigate the problem of endogeneity, they follow an IV-regression approach with past outsourcing intensity as instrument. They find that outsourcing leads in the chemical and especially in the engineering sector to firms experiencing a positive productivity effect, but not in the electronics sector. Those effects are larger for foreign owned firms.

Hijzen et al. (2009) examine, besides employment effects, also productivity effects of French firms through off-shoring. They distinguish between manufacturing and service sectors and horizontal and vertical FDI. They find large but imprecise positive productivity gains through vertical FDI, but no productivity gains through horizontal FDI or off-shoring in the service sector.

Görg et al. (2008) focus on the plant level. Detailed Irish plant data from 1990 – 1998 enables the calculation of TFP and a distinction between international outsourcing of materials and services. Many different econometric techniques, like fixed effects and IV regressions, were used to mitigate endogeneity problems. They find that for exporting plants, independent of being foreign owned or not, outsourcing of services has a positive impact on TFP.

To summarise, the effect of fragmentation on labour productivity depends on the industry of the firm, the industry of the outsourced production stage and whether short- or long-run effects are considered.

2.3.3. Implications of the literature

We conclude this chapter by illustrating what hypotheses and methods are being derived from the literature for consideration in this thesis. We show this for each of the following chapters separately.

Are UK firms becoming more fragmented?

Measure of fragmentation: We are going to use a measure for organisational and spatial fragmentation. The organisational measure is based on input-output tables, similar to Davies and Morris (1995) and Acemoğlu et al. (2010). For the degree of spatial dispersion the distance between local units will be used.
Expectations of results: Based on Davies and Morris (1995) and Acemoğlu et al. (2010) we expect a low degree of vertical integration at the firm level. The literature provides a heterogeneous picture about the change in the degree of fragmentation, because many different measures, industries and minimum firm sizes have been used. The increase in international off-shoring leads us to expect that firms got spatially more dispersed over time.

Explanations for the organisational structure of firms

Causes of Fragmentation: Theory suggests that knowledge capital, technology and incomplete contracts are the driving forces behind organisational fragmentation. Factor-price differences should be crucial for spatial fragmentation.

Expectations of results: The empirical literature highlights the importance of those factors. Even within the UK factor-price differences exists and should therefore matter for spatial fragmentation.
Methods used: Estimation will be based on Acemoğlu et al. (2010), using dummies and continuous integration measures as dependent variables and a linear probability model as estimator, which allows us to employ firm fixed effects.

The effects of fragmentation on employment and productivity

Effects of fragmentation: Outsourcing can have positive effects on employment in the medium-rum, because firms start to focus on their core activities and will get more competitive, which can create new jobs within the firm. Focusing on the core activity will also have a positive effect on the productivity of the firm.
Expectations of results: While the theory is quite clear, the empirical evidence is not as straightforward. Positive and negative employment effects can be found. Also the results for productivity are not as clear as expected.
Methods used: Estimation will be based on Hijzen et al. (2010) and Hijzen et al. (2009) using a Difference-in-Difference estimator which compares firms which outsource with firms which did not.

3. The Business Structure Database: A Portrait of UK Firms and Establishments 1997 – 2008

The Business Structure Database (BSD), provided by the UK Office for National Statistics (ONS) provides information about all UK firms and local units which are registered for UK VAT or part of the PAYE scheme for the period 1997 – 2008. 99 percent of UK economic activities are captured by this data. The outline of this chapter is as follows: First, the data sources of the BSD will be discussed. Second, the three levels of observation, local units, enterprises and enterprise groups, will be defined. Third, the available information of the BSD will be presented. Before using the BSD the data has to be cleaned. This cleaning procedure is discussed in the fourth section. A quick summary of the most important changes of the UK company landscape is part of section 5. In section 6 we discuss an alternative source of data to the BSD, the Annual Respondent's Database (ARD) and compare the two datasets. Conclusions will be presented in section 3.7.

3.1. Data Sources

The BSD is based on the Inter Departmental Business Register (IDBR) which is a live register of UK firms and was introduced in the mid 1990s. Multiple sources are employed to gain information and reach a high degree of coverage of UK entities. Those sources are the Value Added Tax (VAT) system, the Pay-As-You-Earn (PAYE) system, Companies House (CH) data and the Annual Register Inquiry (ARI). Other minor sources are the Ministry of Agriculture, Fisheries and Food (MAFF) for the agricultural sector and the Department of the Environment, Transport and the Regions (DETR) for the construction sector. The ONS is only responsible for collecting data on British firms, while Northern Irish firms are recorded by the Department of Enterprise, Trade and Investment Northern

Ireland (DETINI).[51]

The strength of the IDBR is that 99 percent of all economic activities are covered. ONS (2006) reports that companies which are too small to be registered for VAT, or do not apply for the PAYE system, are not included. Those firms will be mainly self-employed proprietors and partnerships. Data on self-employed individuals is legally prohibited from being transferred to the ONS (ONS, 2001). Even if their relative importance in terms of economic output is very low, the estimated number of those firms is actually higher than of all registered firms together.[52] Another possible source of *undercoverage* occurs if one of the IDBR data source classifies a reporting unit as dead and removes it from the Register, even though it is still trading. A reporting unit holds the mailing address for the business and is the unit for which businesses report their survey data to the ONS (ONS, 2001, p. 17). *Overcoverage*, on the other hand, can appear if dead firms are still in the sample and because of duplicates (ONS, 2001, p. 33). Duplicates can arise if PAYE information cannot be matched with the VAT data. The main sources of the IDBR are briefly discussed below:[53]

VAT: All businesses with a turnover above £73,000[54], with some exceptions in the health and education industry, have to register at the Her Majesty's Revenue and Customs (HMRC)[55], which provides data to the ONS. Turnover is gained from this source.

PAYE: Data of employers who are part of the PAYE scheme are recorded by the HMRC. PAYE is defined by the HMRC as "*... the system that HM Revenue & Customs (HMRC) uses to collect Income Tax and National Insurance contributions (NICs)*

[51] See ONS (2001), pages 15*f*.

[52] Out of 4.3m UK in a year around two million firms are part of the register. Still 99 percent of UK economic activity is captured by the IDBR (ONS, 2006, p. 9).

[53] Table 3.2 reveals which information of the BSD comes from which source.

[54] See `http://www.hmrc.gov.uk/vat/start/register/when-to-register.htm`, access on 24/08/11.

[55] When ONS (2001) was published two separated institutions, the Her Majesty's Customs and Excise (HMCE) and the Inland Revenue (IR), existed. They merged in 2005 to the HMRC. Therefore throughout the thesis it will always be referred to the HMRC.

from employees' pay as they earn it."[56] Employers have to deduct the tax and NICs from employees pay each pay period. Not every employer has to register. If any of following conditions applies, registration is necessary:[57]

- the employee already has another job
- employees are receiving a state or occupational pension
- employees are paid at or above the PAYE threshold (£7,475 per year)
- employees are paid at or above the National Insurance Lower Earnings Limit (£5,304 per year)
- employees are receiving employee benefits

The data available is similar to the VAT data, so if a company does not surpass the VAT threshold, then data might be used from PAYE instead.

CH: All companies which want to have limited liability have to register at CH first (see ONS, 2006, page 5). The main aim of the CH data is to connect VAT and PAYE information with each other by using the legal names of the companies.

ARI: This survey data is mainly used to check and update the IDBR and to provide information about employment at the local unit level for the Annual Business Inquiry (ABI), which on its own is used as source for the IDBR. The ARI is the successor of the Annual Employment Survey (AES) and was introduced in July 1999. Large companies are covered every year (employment > 100) and medium sized companies every four years (employment $20 - 99$). Around 68,000 enterprises were part of the survey at the beginning, and around 400,000 local units were covered.[58]

[56]See `http://www.hmrc.gov.uk/paye/intro/basics.htm`, access on 04/01/12.
[57]See `http://www.hmrc.gov.uk/paye/intro/register.htm`, access on 04/01/12.
[58]See Jones (2000), page 51.

D&B: Dun and Bradstreet (D&B) is a private business information supplier and used by the ONS to create and update information at the enterprise group level. Additionally, it is the main source to identify foreign ownership of firms.

3.2. Local Units, Enterprises and Enterprise Groups

Two separate databases exist, one including information on enterprises and another one consisting of basic information of local units. Local units and enterprises can be linked to an enterprise group. The ONS uses the EU Regulation on Statistical Units (EEC 696/93) for its categorisation:[59]

Local Unit: The local unit is an enterprise or part thereof (for example a workshop, factory, warehouse, office, mine or depot) situated in a geographically identified place. At or from this place economic activity is carried out for which – save for certain exceptions – one or more persons work (even if only part-time) for one and the same enterprise.

Enterprise: The enterprise is the smallest combination of legal units that is an organisational unit producing goods or services, which benefits from a certain degree of autonomy in decision-making, especially for the allocation of its current resources. An enterprise carries out one or more activities at one or more locations. An enterprise may be a sole legal unit.

Enterprise Group: An enterprise group is an association of enterprises bound together by legal and/or financial links. A group of enterprises can have more than one decision-making centre, especially for policy on production, sales and profits. It may centralise certain aspects of financial management and taxation. It constitutes an economic entity which is empowered to make choices, particularly concerning the units which it comprises.

[59] This description was taken from ONS (2006), page 7.

In other words, local units are the actual physical premises of a company (for example factories, outlets, etc.). In this thesis, in common with much of the literature, we will also refer to them as “establishments” or “plants”. An enterprise can consist of one or more local units, if it is the former case I will refer to them as single-plant, and if the latter is the case, as multi-plant firms. The enterprise and local unit database can be merged easily because every local unit can be connected to a company by using an enterprise reference number. Additionally, an enterprise group reference number can be used to combine firms of the same group. The raw data for local units and enterprises is presented in table 3.1. Note that the number of business units increased massively from 2.2m firms and 2.8m local units in 1997 to 3.9m firms and 5.1m local units in 2008. However, this large increase is mainly caused by inactive firms. Active firms are identified as enterprises with at least one local unit for which live data is available. Live data can be unavailable if a firm stops trading or falls below the VAT threshold (Evans and Welpton, 2009). In table 3.13 we can see that the number of inactive local units increased from around 200k to 1.5m. After a first, cleaning the actual number of firms just increased from 1.8m to 2.2m firms and not from 2.2m to 3.9m.

	Enterprises	**Local Units**
1997	2,179,819	2,800,732
1998	2,305,178	3,203,902
1999	2,498,186	3,181,018
2000	2,514,592	3,196,472
2001	2,545,284	3,293,706
2002	2,587,018	3,388,364
2003	2,843,291	3,809,199
2004	2,931,311	3,868,864
2005	2,974,762	3,866,165
2006	3,302,135	4,266,324
2007	3,574,241	4,711,449
2008	3,868,126	5,119,814
Total	34,123,943	44,706,009

Table 3.1: Raw data for number of enterprises and local units

3.3. Available Information

The BSD reports information at the local unit and at the enterprise level. The data available at the enterprise level is a little bit more comprehensive. Table 3.2 summarises the variables included followed by a detailed description.

Variable	**Description**	**Enterprise**	**Local Unit**	**Source**[1]
Entref	Enterprise Reference Number	✓	✓	
Luref	Local Unit Reference Number		✓	
WOWref	Enterprise Group Reference Number	✓	✓	
Employment	—	✓	✓	PAYE
Employees	—	✓	✓	PAYE
Turnover	—	✓		VAT
SIC - Industry	5 digit, SIC 03 and SIC 07 [2]	✓	✓	VAT
Postcode	8 digit Postcode	✓	✓	VAT
Gor	Government Office Region	✓	✓	
Inactive	Dummy	✓		CH
Birth	Year	✓	✓	
Death	Year	✓	✓	
Death Code	Reason for death		✓	
Status	Legal Status	✓	✓	VAT
Imm_foc	Immediate Foreign Ownership	✓	✓	D&B[4]
Ult_foc	Ultimate Foreign Ownership	✓	✓	D&B[4]
Live_LU	Number of live local units	✓		
Live_RU	Number of reporting units	✓		
live_paye	live PAYE indicator	✓		
live_vat	live VAT indicator	✓	✓	
Demvar	Demographic event identifier[3]	✓	✓	
Demvarred	Dem. event ident. for Local Unit		✓	
DTIref	DTI reference number scheme	✓	✓	

Notes:
[1] Main sources for IDBR, can by updated and extended by other sources, see ONS (2001).
[2] SIC 07 is only available for 2008.
[3] Missing for enterprise data in 1997.
[4] Dun and Bradstreet.

Table 3.2: Variables in BSD, based on ONS (2006), page 23, altered by author

Reference numbers

According to ONS (2006) an important feature of the database is that local unit reference numbers are consistent over time, meaning that it is unaffected by mergers or acquisitions. Even if a local unit shuts down, it still will be kept in the sample as inactive local unit. In contrast to that statement, ONS (2006), on pages 18*ff*, states that the main focus of the database is put on accuracy of a business activity at a single point of time rather than continuity over time, therefore there is a possibility that the local unit reference numbers are not always consistent over time. To check those statements an independent local unit ID will be created, by using certain local unit characteristics. This ID number is based on a local unit postcode, local unit industry classification and the year of birth. Even if two local units have the same postcode, by using the industry classification and the year of birth, allocating a unique ID number will be possible. A dummy is then created which shows when a local unit appears and disappears from the data. Finally, if a local unit (reference number) within a firm disappears in period t and a new local unit (reference number) appears in the same firm in $t+1$, but the local unit ID of the new local unit is the same of the exited local unit, then the local unit reference number can be seen as inconsistent. Table 3.3 illustrates this procedure with an example. Enterprise A has three local units in 1997 and 1998. Retail shop 02 disappears from the data, but a "new" retail shop appears a year later. The local unit ID calculated by some characteristics would reveal that local unit 04 is in reality local unit 02.

Year	**Entref**	**Luref**	**Poco**	**SIC 03**	**Birth**	**Luref$_{\text{id}}$**	**Entering**	**Exiting**
1997	A	01	NG9	17	1969	1	0	0
1997	A	02	M1	52	1990	2	0	1
1997	A	03	DE7	70	2000	3	0	0
1998	A	01	NG9	32	1969	1	0	0
1998	A	04	M1	52	1990	2	1	0
1998	A	03	DE7	70	2000	3	0	0

Table 3.3: Local unit reference number reliability check: an example

The reliability check has been conducted for firms in the manufacturing sector. One problem is that even though full postcodes, 5 digit Standard Industrial Classification (SIC) codes and the year of birth have been employed, the local unit ID is not unique, see table 3.4. This occurs because a firm can have multiple observations with the same postcode and date of birth. Around 93,600 observations have a local unit ID appearing more than once. Before the reliability check can be conducted, it has to be taken care of those suspicious units first. We can only keep those duplicates, where the number of appearances is two and if they have the same exiting and entering pattern. If they have not we cannot allocate the appearance and disappearance pattern to the local unit ID.

Appearance	**Frequency**
1	1,731,685
2	72,806
≥3	20,832
Total	1,825,323

Table 3.4: Number of local units with the same local unit ID

The results from the procedure explained are presented in table 3.5. The number of observations differs from table 3.1 because we only consider the manufacturing sector. The number of unreliable local unit reference numbers is quite low until 1999 but increasing from 2000 onward, for example the number of local units which changed their local unit reference number within a firm was 177 in 1997 but 1,761 in 2004. In total only 0.7 percent of observations in manufacturing are potential data errors. So the change of local unit reference number for a specific local unit within a firm over time is very unlikely, but do the observations where it does happen affect the analysis of fragmentation of UK firms? The answer is no. Static analysis of this thesis is not affected by it. It is also not a problem for the dynamic analysis because even if the local unit reference number changes, it will not change the characteristics of an enterprise.[60]

[60]For example, the main focus of the dynamic analysis is on the firm level. To be classified as a vertically integrated firm, it is only important that vertically integrated local units exist. If the local units are

Year	Reliability		Total
	0	1	
1997	175,216	177	175,393
1998	175,932	107	176,039
1999	170,069	790	170,859
2000	158,970	1,350	160,320
2001	155,782	1,480	157,262
2002	151,727	1,341	153,068
2003	144,388	1,606	145,994
2004	140,516	1,761	142,277
2005	136,804	1,482	138,286
2006	133,442	1,431	134,873
2007	132,571	1,372	133,943
Total	1,675,417	12,897	1,688,314

Table 3.5: Reliability of Local Unit Reference Numbers

Every local unit can be allocated to an enterprise through reference numbers. The majority of firms only consist of one local unit. Theoretically all enterprises can be connected to enterprise group reference numbers, which represents the ultimate stage of aggregation. There are some issues with the enterprise group reference number, especially its inconsistency over time. There was a change of the enterprise group reference number in 1997 which affects the years 1997 and 1998 in the BSD sample, because those changes have not been updated. As suggested by Criscuolo and Martin (2007) two look-up tables offered by the ONS can be used to update those numbers, but unfortunately these look-up tables are not complete. In contrast to the local unit or enterprise reference numbers, the enterprise group is not suitable for panel data analysis. After 2005 the number of missing enterprise group reference numbers is so severe that the last three years (2006 – 2008) cannot be used for analysis anymore.

called A or B does not affect the classification. The characteristics and not reference number of the local units are important.

Employment, employees and turnover

The ONS defines those three variables as follows:

- "***Turnover*** *is defined as Total sales and work done. This is calculated by adding to the value of Sales of goods produced, Goods purchased and resold without further processing, Work done and industrial services rendered and Non industrial services rendered*" (ONS, 2010, page 5).
- **Employment** is defined as "*...full and part time employees on the payroll plus the number of working proprietors employed*" (ONS, 2010, page 6).
- **Employees** are defined as employment minus the number of working proprietors employed (ONS, 2001, page 80).

The amount of employment, employees and turnover are available at the enterprise level and employment and employee figures also at the local unit level. The enterprise level is generated by adding up the local unit figures. Turnover data is delivered by the HMRC. Turnover data for new businesses is estimated in advance by the companies concerned and is a potential source of inaccuracy.[61] Another problem is that many firms with a turnover of zero exist, but which are still active. Some of these firms report zero turnovers for the whole observation period, even though a firm, once it is in the data, should provide information about its turnover. A further concern is that for some companies the turnover rate fluctuates massively over time, and unrealistic increases or decreases are reported. For example, some firms have a turnover of a couple of millions in one period, followed by a period where turnover increases to a couple of billions, before it returns to a "reasonable" level. This can have a significant impact on descriptive statistics. These problems mainly arise in the financial sector. To deal with the problems we cleaned the samples and dropped all four digit SIC industries with extremely volatile aggregate turnover figures, because there are too many firms with suspicious turnover figures. Furthermore, the

[61] See ONS (2001), page 41 and pages 43*f*.

selection of the suspected outlier firms would be rather arbitrary. A detailed description of the cleaning process can be found in section 3.4. The summary statistics for turnover of the cleaned samples are reported in table 3.6 and all values are presented at current prices.

All statistics about employment and turnover are presented separately for the manufacturing and the tradable service sector. The latter comprises all service which do not require proximity to their customers, for example a call centre. Both the level and time-series development of employment and turnover are very different for these sectors, and grouping them would disguise some important developments. On pages 88*ff* this classification will be discussed in more detail. The manufacturing sample is presented on the left side of the table. The right side shows the tradable service sample. For each sample we present descriptive statistics for all firms, for multi-plant firms and for single-plant firms. A first look reveals that the majority of firms are single-plant firms. Nevertheless, total turnover is mainly generated by multi-plant firms in the manufacturing sector. The massive increase in the number of single-plant firms in the tradable service sector leads to the situation where 68 percent of turnover comes from single-plant firms in 2008.

The cleaned and the full sample are significantly different in the tradable service sector. According to the data, total turnover of tradable services sample before cleaning decreased from £2,800bn to £1,500bn between 1997 – 2008, even though the number of firms is increasing massively. The financial sectors are causing that problem. After dropping those sectors the sample is reduced by about 50,000 observations. The total turnover decreased to £105bn in 1997 and to £247bn in 2008. To check how reasonable the sample with the financial sector is, the turnover data of the BSD will be compared with the production data of the OECD Structure Analysis Database (STAN). Table 3.7 shows that the BSD sample overstates actual turnover massively. In 1997 the turnover is more than twelve times higher than in the STAN, but decreases to more than two and a half times in 2008. Dropping the problematic financial sectors will create more sensible

		Turnover							
		Manufacturing				Tradable Services			
	Year	Mean[1]	S.D.[1]	Freq.	Total[1]	Mean[1]	S.D.[1]	Freq.	Total[1]
All firms	1997	2.18	43.08	159,401	348,225	0.35	8.09	299,299	104,683
	1998	2.20	41.47	161,701	356,047	0.33	4.68	339,754	113,510
	1999	2.37	44.83	157,013	372,320	0.37	8.63	363,462	134,325
	2000	2.50	47.17	147,548	369,445	0.38	8.41	378,593	144,529
	2001	2.55	57.49	145,479	371,079	0.40	8.62	391,474	157,385
	2002	2.55	42.36	142,141	361,827	0.46	12.69	397,179	183,301
	2003	2.52	41.58	137,365	346,774	0.47	11.57	402,219	187,773
	2004	2.58	42.47	133,220	343,651	0.43	8.01	429,603	184,424
	2005	2.62	45.42	129,106	338,554	0.41	7.39	458,257	187,268
	2006	2.80	52.07	125,763	352,148	0.41	7.37	489,681	201,458
	2007	2.88	54.15	124,679	358,872	0.43	8.87	520,929	221,778
	2008	2.92	52.81	123,555	361,089	0.45	9.39	547,899	246,937
Multi-plant firms	1997	22.07	172.21	9,484	209,353	3.87	23.40	8,483	32,869
	1998	25.59	178.07	8,364	214,003	4.23	24.29	7,916	33,491
	1999	28.06	192.89	8,046	225,781	5.78	55.77	7,617	43,998
	2000	31.30	207.45	7,243	226,740	6.48	56.61	7,134	46,241
	2001	32.46	249.95	7,159	232,350	6.77	52.87	7,501	50,785
	2002	31.75	182.97	7,107	225,674	7.93	69.67	7,675	60,863
	2003	30.91	178.43	6,701	207,143	7.94	50.22	7,569	60,071
	2004	32.88	184.28	6,434	211,545	8.41	53.21	7,543	63,442
	2005	35.11	202.22	5,905	207,310	9.20	52.67	6,785	62,456
	2006	39.91	240.17	5,446	217,363	10.05	55.19	6,498	65,332
	2007	42.50	251.57	5,240	222,704	11.73	71.64	6,485	76,068
	2008	45.11	255.22	4,912	221,578	12.49	68.87	6,346	79,285
Single-plant firms	1997	0.93	8.43	149,917	138,872	0.25	7.14	290,816	71,815
	1998	0.93	7.27	153,337	142,044	0.24	2.83	331,838	80,020
	1999	0.98	8.44	148,967	146,539	0.25	2.98	355,845	90,328
	2000	1.02	8.59	140,305	142,705	0.26	3.14	371,459	98,288
	2001	1.00	13.93	138,320	138,729	0.28	4.51	383,973	106,601
	2002	1.01	8.94	135,034	136,153	0.31	8.22	389,504	122,438
	2003	1.07	11.90	130,664	139,631	0.32	9.33	394,650	127,703
	2004	1.04	11.11	126,786	132,107	0.29	3.68	422,060	120,982
	2005	1.07	12.22	123,201	131,244	0.28	3.55	451,472	124,812
	2006	1.12	12.59	120,317	134,784	0.28	3.58	483,183	136,126
	2007	1.14	14.60	119,439	136,168	0.28	3.66	514,444	145,709
	2008	1.18	11.48	118,643	139,510	0.31	5.65	541,553	167,653

Notes:
[1] . . . figures in millions of £

Table 3.6: Detailed statistics of BSD turnover

results for the remaining tradable service sector.

Table 3.9 compares the cleaned BSD sample with other databases to see how much of the total UK sales and employment is covered by the sample. The other sources are the ABI of the ONS and the STAN of the OECD. The ABI uses a stratified random sample of about 67,000 businesses (2008) to calculate the whole population of UK firms. For the manufacturing and the tradable service sector the cleaned BSD sample covers more than 70 percent of the respective total UK turnover. This is reasonable because, as mentioned before, not the whole population is included in the BSD and some sample selection rules had to be applied before using the BSD.[62]

The second comparison is with the STAN. The production data for manufacturing and tradable services is in accordance with the turnover data in ABI.[63]

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
STAN	228	252	282	299	328	349	371	383	407	440	472
$\mathbf{BSD_{full}}$	2,808	2,256	2,127	2,142	1,673	1,514	1,114	1,553	1,552	1,318	1,295

Notes:
All values are in bn £. In contrast to BSD's UK SIC 2003 classification, ISIC Rev3 is used for classification of OECD's STAN database. While BSD data contains turnover, data presented in STAN column is production data.

Table 3.7: Comparison of the tradable service sector in BSD including financial sectors and STAN

Employment figures are collected by the HMRC through the PAYE system. The calculation of local unit employment data requires the ARI, which is part of the ABI. For companies, for which only information from VAT is available, employment data is estimated through turnover data and can be a source of misleading data.[64] Because there is

[62]Below the sample selection rules will be explained in detail. For example, in that sample only firms are included which have always been part of manufacturing. All non-private businesses have been excluded.

[63]Production and turnover is not exactly the same, because production represents the value of goods and/or services produced in a year, whether sold or stocked. Turnover represents only the value of goods and/or services sold. See `http://oecd-stats.ingenta.com/OECD/TableViewer/summary.aspx`, access on 04/05/2010. Because many services cannot be stocked, the difference between turnover and production should not be too big.

[64]See ONS (2001), page 33.

hardly any difference in the values of employment and employee data only the statistics for the first one will be presented.[65] While employment in the manufacturing sector is decreasing massively from 3.8m to 2.5m, it is increasing for the tradable service sector from 1.93m to 2.96m. See table 3.8. The comparison of the BSD and ABI data shows that the BSD underestimates the whole population of employment.

Table 3.9 compares again the cleaned BSD data with the ABI and STAN. On average more than 80 percent of people employed are covered by the BSD, regardless the sector. STAN employment data is only available for the manufacturing sector and overstates actual employment slightly.

Locational variables

To every enterprise or local unit an eight digit postcode is allocated. Unfortunately a large number of local units have a missing postcode in 2003, and we therefore impute this information.[66] [67]

According to the ONS the postcode of an enterprise does not necessarily represent the postcode of its headquarters, because the postcode provided in the BSD indicates the location of the reporting unit. A enterprise can have also several reporting units for different areas and different divisions. To check if it can be assumed that the location of the reporting unit is a good approximation for the location of the headquarters, the Financial Analysis Made Easy Database (FAME) is used. This database allows us to identify the headquarters and its location in the BSD. Through a look-up table FAME's Company Reference Number (CRN) and BSD's enterprise reference number can be matched. Ritchie and Evans (2009) could only match half of the data for the year 2007. This was

[65] The number of employee is slightly lower than the number of employment.

[66] Imputation rules are explained in section 3.4.

[67] Original postcode data is only available if the BSD is used in the Virtual Microdata Laboratory (VML). If the online access via Secure Data Service (SDS) is used, all postcodes are encrypted. The main characteristics of the new postcodes are similar to the original ones, so analysis using geographical data can still be conducted without any loss of information.

		Employment							
		Manufacturing				Tradable Services			
	Year	Mean	S.D.	Freq.	Total	Mean	S.D.	Freq.	Total
All firms	1997	23.90	245.03	159,401	3,809,987	6.45	125.38	299,299	1,929,300
	1998	22.76	226.36	161,701	3,680,178	5.78	99.83	339,754	1,965,039
	1999	22.99	228.48	157,013	3,610,501	5.56	98.30	363,462	2,020,690
	2000	23.79	222.73	147,548	3,510,103	5.62	95.18	378,593	2,126,975
	2001	23.15	220.33	145,479	3,368,290	5.66	89.13	391,474	2,216,757
	2002	23.29	204.06	142,141	3,310,937	5.95	86.63	397,179	2,361,977
	2003	22.49	192.59	137,365	3,088,922	5.93	97.59	402,219	2,385,589
	2004	22.11	192.84	133,220	2,944,967	5.61	98.80	429,603	2,408,468
	2005	21.35	190.56	129,106	2,757,034	5.52	101.77	458,257	2,528,491
	2006	21.05	186.38	125,763	2,646,871	5.62	116.59	489,681	2,751,943
	2007	20.36	184.87	124,679	2,537,966	5.38	110.33	520,929	2,800,292
	2008	20.01	183.84	123,555	2,472,859	5.41	122.95	547,899	2,964,204
Multi-plant firms	1997	206.86	940.99	9,484	1,961,845	83.25	516.74	8,483	706,197
	1998	222.85	954.38	8,364	1,863,946	92.02	626.05	7,916	728,439
	1999	228.32	967.57	8,046	1,837,058	98.27	658.31	7,617	748,505
	2000	244.05	955.63	7,243	1,767,655	107.09	667.72	7,134	763,948
	2001	237.83	909.34	7,159	1,702,598	108.64	614.07	7,501	814,902
	2002	234.68	857.06	7,107	1,667,871	109.01	591.80	7,675	836,619
	2003	227.88	804.32	6,701	1,527,006	116.45	687.83	7,569	881,405
	2004	229.45	827.95	6,434	1,476,254	117.51	722.75	7,543	886,349
	2005	231.44	840.25	5,905	1,366,678	139.66	809.24	6,785	947,584
	2006	238.36	841.69	5,446	1,298,124	159.89	979.58	6,498	1,038,981
	2007	239.48	852.61	5,240	1,254,869	160.59	956.63	6,485	1,041,429
	2008	247.23	870.93	4,912	1,214,380	171.50	1,040.54	6,346	1,088,363
Single-plant firms	1997	12.33	74.68	149,917	1,848,142	4.21	90.63	290,816	1,223,103
	1998	11.84	45.33	153,337	1,816,232	3.73	25.95	331,838	1,236,600
	1999	11.90	45.44	148,967	1,773,443	3.58	20.15	355,845	1,272,185
	2000	12.42	48.95	140,305	1,742,448	3.67	21.68	371,459	1,363,027
	2001	12.04	75.88	138,320	1,665,692	3.65	22.86	383,973	1,401,855
	2002	12.17	51.97	135,034	1,643,066	3.92	23.20	389,504	1,525,358
	2003	11.95	59.54	130,664	1,561,916	3.81	19.86	394,650	1,504,184
	2004	11.58	44.73	126,786	1,468,713	3.61	19.34	422,060	1,522,119
	2005	11.29	44.76	123,201	1,390,356	3.50	19.95	451,472	1,580,907
	2006	11.21	44.88	120,317	1,348,747	3.55	23.44	483,183	1,712,962
	2007	10.74	39.90	119,439	1,283,097	3.42	22.02	514,444	1,758,863
	2008	10.61	39.67	118,643	1,258,479	3.46	47.76	541,553	1,875,841

Table 3.8: Detailed statistics of BSD employment

	Manufacturing								
	Number of enterprises[1]			Total turnover[2]			Total employment[3]		
Year	BSD[4]	ABI	STAN[5]	BSD[4]	ABI	STAN[5]	BSD[4]	ABI	STAN[5]
1997	159	170	—	348	470	409	3.81	—	4.52
1998	162	169	—	356	461	408	3.68	4.42	4.54
1999	157	170	—	372	462	405	3.61	4.27	4.37
2000	148	167	—	369	469	415	3.51	4.14	4.23
2001	145	165	—	371	462	412	3.37	3.97	4.06
2002	142	162	—	362	450	406	3.31	3.76	3.86
2003	137	158	—	347	448	404	3.09	3.53	3.68
2004	133	155	—	344	460	413	2.94	3.41	3.51
2005	129	153	—	339	472	429	2.76	3.25	3.36
2006	126	151	—	352	483	448	2.65	3.15	3.25
2007	125	149	—	359	504	—	2.54	3.07	3.20
	Tradable Services								
1997	299	319	—	105	136	117	1.93	—	—
1998	340	347	—	114	158	141	1.97	2.58	—
1999	363	397	—	134	174	157	2.02	2.75	—
2000	379	415	—	145	189	176	2.13	2.93	—
2001	391	425	—	157	199	191	2.22	3.11	—
2002	397	432	—	183	204	204	2.36	3.14	—
2003	402	429	—	188	216	218	2.39	3.12	—
2004	430	444	—	184	228	229	2.41	3.20	—
2005	458	476	—	187	252	241	2.53	3.40	—
2006	490	499	—	201	271	253	2.75	3.37	—
2007	521	534	—	222	307	—	2.8	3.57	—

Notes:
[1] in thousands, [2] in billions of £ and [3] in millions.
[4] cleaned BSD sample is presented
[5] Includes SIC 72.5, 74.15, 74.6, 74.7. STAN uses ISIC Rev3 while BSD is based on UK SIC 2003. BSD shows turnover data, STAN production data. As in the BSD, current prices are presented.

Table 3.9: Comparison of BSD sample with ABI and STAN

mainly caused by differences in timing and different inclusion criteria. The cleaned BSD manufacturing sample contains only private companies, therefore a higher matching rate is expected. Different timing of recording should cause no problems, because the interest does not lie on financial information for which the recording time could be crucial.

16,947 observations of the manufacturing sector are available from FAME in 2009. The VML offers two look-up tables which match the CRN with enterprise reference numbers. The updated look-up table from 2007 will be used. 98 percent of companies within FAME can be linked to a BSD enterprise reference number from the look-up table. Because headquarters can move over time we only merge FAME with the BSD sample for the period 2005 – 2008.[68] Only between 7,700 to 7,900 out of 16,947 of observations can be matched between 2005 and 2008. Table 3.10 shows the result. Because only multi-plant firms are of interest, the remaining observations are largely reduced. Out of a total of 9,300 firms from 2005 – 2008 about 5,800 can be matched with a postcode of the BSD. For 4,850 firms the postcode of the reporting unit equals the postcode of the headquarters, which is about 84 percent. Even though this number seems to be high, it has to be interpreted carefully. We can only match a rather small sample of firms of the BSD and FAME. The obtained matches may favour small firms with few plants, and therefore show little in terms of reporting units and headquarters of large firms.

Year	All firms	Multi-plant firms	HQ found	Firms where RU = HQ
2005	7,722	2,331	1,376	1,161
2006	7,816	2,300	1,414	1,179
2007	7,917	2,349	1,494	1,247
2008	7,910	2,297	1,500	1,263
Total	31,365	9,277	5,784	4,850

Table 3.10: Reliability check of headquarters location using FAME

[68]The number of firms in the BSD of 1997 which can be merged to FAME 2009 is only about a half of the number of firms which can be merged in 2008.

Industry classification

The BSD includes a five digit UK Standard Industry Classification of 2003 (SIC 03) for every enterprise and local unit.[69] If an enterprise consists of one local unit, the industry classification will represent the activity, which involves the highest share of employees of the company. However, if a company with one local unit is running several activities, and all of them are about the same size, then important activities of that company may be camouflaged by the data (Hellebrandt and Davies, 2008). The classification of multi-plant firms works differently and is illustrated by a table 3.11. The enterprise industry classification will be similar to the code of the dominant local unit. Dominance is identified by looking at the number of people employed in local units of a specific industry. After identifying the one digit industry with the highest number of employees, the same procedure will be conducted again within this industry at the two digit SIC level, followed by the three digit industry level, etc.

Enterprise	Local Unit	SIC Code	Employment
A	01	33500	45
A	02	52111	20
A	03	52112	10
A	04	52210	25
B	05	33500	40
B	06	29410	15
B	07	52111	25
B	08	52210	20

Table 3.11: The determination of an enterprise activity based on Hellebrandt and Davies (2008)

Enterprise A consists of four local units, where local unit 01 is an establishment in the manufacturing sector and 02 – 04 in the service sector. Even though 01 is the biggest local unit it is not the dominant local unit. The majority of workers are part of the service sector 5 and within this sector of industry 52 followed by industry 521. Finally

[69] For the year 2008 also SIC 07 is available.

in sector 521 the largest local unit is 02, therefore the company will be categorised as a company in sector 52112. Enterprise B has local unit 07 as dominant establishment and is classified as enterprise of the service sector, even though the majority of employees is located within the manufacturing sector. The problem is that the manufacturing activities are within two different one digit industries. Local unit 05 of industry 33 has 40 employees, but local units active in industry 52 have in total 45. Because 07 is larger than 08, local unit 08 is the dominant local unit. Therefore the industry classification at the enterprise level can sometimes be rather imprecise. It can even be the case that firms with more people employed in manufacturing plants than in service local units are still classified as service firms.

Birth, death and activity

The BSD does not contain only trading companies but also companies which have ceased trading already. Through an active/inactive dummy it is possible to identify those enterprises. In 2008 1.5m (38%) enterprises out of 3.9m of the full sample were inactive. Additional information exists about the date of birth or death of an enterprise or local unit. The date of birth and the date of death represents the actual year of appearance and the year of closure. Mergers, take-overs, break-ups and split-offs do not affect the year of birth or death of a company.

The birth data for enterprises is censored at 1973. According to the ONS, the reason for that is that the VAT system was introduced in 1973, since IDBR is based on VAT records, the BSD presents the year of birth of 1973 even if they firms are older. At the local unit level the date of birth and death and, instead of the active/inactive dummy, a deathcode exist. Thirteen different ways of dying can be identified[70], but the ONS recommends to use the year of death for the identification of dead local units. In contrast to the firm

[70]See ONS, 2006, page 21.

level the year of birth at the local unit level is not censored.

Legal status and foreign ownership

The BSD classifies the legal status of an enterprise or local unit into seven different categories: company, sole proprietor, partnership, public corporation, central government body, local authority and non-profit making body.

Information about immediate and ultimate foreign ownership is available from D&B. Both variables include a country code and reveal the location of the parent company. Unfortunately the country classification changes over time, for example from a three digit country code to a two letter code. Figure 3.1 and table 3.12 show how many firms in the UK are foreign owned using the two cleaned samples for manufacturing and tradable services sector. The value 0 stands for domestic and 1 for foreign ownership. It seems that in both sectors the degree of foreign ownership is increasing but this might be caused by missing values, which completely disappear in 2008. Still, it can be seen that in manufacturing the highest degree of foreign ownership is prevailing with 1 – 2.7 percent in comparison to 0.2 – 1 percent in the tradable service sector.

Other variables

The variables "Live_Lu" or "Live_Ru" show the number of live local units or reporting units per enterprise. Comparing the "Live_Lu" variables with the number of local units in the BSD shows that the numbers are nearly identical. Less than one percent of all local units are part of a company for which the Live number is different to the actual number of local units which appear in the BSD. The variables "live_paye" and "live_var" are markers revealing the source of information for every company. The most reliable information is gained when information comes from VAT and PAYE. The "Demvar" and "Demvarred" variables are demographic event identifiers, for example for merges and

Figure 3.1: Share of foreign to total number of UK firms

		Manufacturing			**Tradable Services**		
	Year	0	1	missing	0	1	missing
Enterprises	1997	148,544	1,847	9,010	288,939	835	9,525
	1998	153,022	1,734	6,945	330,783	839	8,132
	1999	148,775	2,331	5,907	354,327	1,487	7,648
	2000	140,000	2,413	5,135	370,120	1,677	6,796
	2001	137,984	2,604	4,891	382,395	2,024	7,055
	2002	134,860	3,101	4,180	387,600	3,201	6,378
	2003	133,855	3,188	322	398,427	3,567	225
	2004	129,507	2,922	791	425,487	3,078	1,038
	2005	125,876	3,077	153	454,209	3,892	156
	2006	122,523	3,093	147	485,560	3,965	156
	2007	121,342	3,324	13	516,092	4,829	8
	2008	120,166	3,389	0	542,484	5,415	0
Local Units	1997	158,818	4,836	17,949	292,689	2,225	24,948
	1998	162,482	4,774	15,062	334,837	2,194	23,872
	1999	159,843	4,873	12,478	360,681	2,575	21,211
	2000	150,729	5,089	10,883	376,191	2,721	20,109
	2001	147,916	5,652	10,423	389,031	3,319	19,364
	2002	143,801	6,977	9,210	394,314	5,015	17,485
	2003	146,195	6,919	720	421,938	5,735	464
	2004	140,936	6,448	1,688	447,380	5,327	2,639
	2005	137,327	6,664	318	476,638	6,294	325
	2006	132,704	7,501	304	515,908	6,608	302
	2007	131,426	7,745	69	549,011	7,674	43
	2008	129,675	8,073	0	556,693	8,525	0

Table 3.12: Foreign ownership statistics

break-ups. Finally "DTIref" is used for the linkage of internal data.

3.4. Cleaning of the Data

This section deals with the data cleaning process and its effects on the sample size, how inconsistent variables can be made consistent and how missing information can be imputed.

3.4.1. Sample size

The BSD covers a major part of the population of UK firms. The raw data consists of over 34m observations for the period 1997 – 2008. Before this raw data is ready for being used for empirical research the data has to be cleaned. Sample selection is complicated by the fact that we have a large 12-year panel. Restricting the sample based on the value of industry in each year can lead to spurious gaps in the data. The only satisfactory way of selecting the sample is to either use characteristics of firms which are constant over time, or select on characteristics which are based on the whole panel. For example, we select only those firms which are always in the manufacturing or service sector. The selection will be conducted in two steps, where only the following firms are kept:

- firms which are not duplicates,
- firms which are active,[71]
- firms which remain in the private sector for the entire period,
- firms which have the legal status of being a company, sole proprietor or partnership,[72]
- firms which have no gaps (for example disappear and reappear later).

[71] The ONS (2006), page 10, defines active enterprises as enterprises "*with turnover and/or persons employed greater than zero and at least one administrative unit linked to the enterprise.*"

[72] Public corporation, central government body, local authority or non-profit making body were dropped.

Those selection rules decrease the number of observations drastically. Duplicates, which are firms which appear twice in the data, are only a problem in 2006. Dropping firms which are inactive reduces the sample by more than 8.3m, which is about 24 percent. Non-Private firms account for about 1m (2.8 percent) observations, and firms with gaps about the same. The sample after the first cleaning is reduced by about 10m to 24m firms. The selection of local units was easier, because only those are kept which are not dead and can be linked to an enterprise.

Year	**Full sample**	**Duplicates**	**Inactive**	**Non-Private**	**Gaps**	**Red. Sample**
1997	2,179,819	0	203,821	69,380	77,286	1,829,332
1998	2,305,178	1	258,155	70,779	75,454	1,900,789
1999	2,498,186	0	424,772	72,297	76,733	1,924,384
2000	2,514,592	1	450,183	75,088	81,229	1,908,091
2001	2,545,284	0	449,818	76,611	88,457	1,930,398
2002	2,587,018	0	479,666	78,552	88,377	1,940,423
2003	2,843,291	0	733,749	80,351	84,208	1,944,983
2004	2,931,311	0	775,355	82,584	80,837	1,992,535
2005	2,974,762	0	773,405	84,376	79,608	2,037,373
2006	3,302,135	45,490	1,009,481	86,270	78,846	2,082,048
2007	3,574,241	0	1,243,880	88,977	85,335	2,156,049
2008	3,868,126	0	1,516,153	89,184	95,052	2,167,737
Total	34,123,943	45,492	8,318,438	954,449	991,422	23,814,142

Table 3.13: Sample size after first cleaning process

A first rudimentary analysis shows that the service sector accounts for about 20m and the agricultural and manufacturing for about 2m firms. Because of its size working with the whole dataset would still be difficult. Therefore the sample will be divided into two subsamples: manufacturing and tradable services. The service sector categorisation is based on the General Agreement on Trade in Services (GATS) mode of transportation classification. Four categories exist where "Mode 1" is of purpose for this chapter.[73] Those services are referred to as "tradable services". Tradable services are characterised by their independence of the proximity to the final customers, for example a call centre

[73]See GATS section at the WTO homepage available at `http://www.wto.org/english/tratop_e/serv_e/serv_e.htm`, access on 04/01/2010.

can be located all around the world and can still serve the domestic market. There are several reasons for splitting the sample, besides the reduction of the sample size. In the theoretical and empirical literature of trade, in general, the manufacturing sector is in focus of attention, but this sector is declining in importance, with regards to turnover, employment and number of enterprises and local units. Common theories may not be able to explain observable patterns in both sectors. For example, transport costs should be more important for manufacturing, but agglomeration effects could be more important for tradable services. Furthermore, by splitting the sample, some empirical issues can be mitigated like omitted variable bias.[74] We focus on the following SIC sectors:[75]

- **Manufacturing**: SIC 15 – 37
- **Tradable services**:
  - **SIC 72**: Data processing and software consultancy
    - excl. **SIC 72.5**: Maintenance and repair of office, accounting and computing machinery
  - **SIC 73**: Research and development services
  - **SIC 74**: Business Services
    - excl. **SIC 74.15**: Management activities of holding companies
    - excl. **SIC 74.6**: Investigation and security activities
    - excl. **SIC 74.7**: Industrial cleaning

[74] For example, it is assumed that both sectors are estimated together, less skilled workers work on average in manufacturing than in the tradable service sector and no data is available on the skill levels of workers. The equation might look like $y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 D^s_{it} + \varepsilon_{it}$ where y_{it} is the degree of vertical integration, X_{it} a matrix of different determinants of integration and D^s_{it} is a service sector dummy. Because we cannot observe the skill level of workers β_2 can be biased. If we just keep the service sector this problem can be mitigated.

[75] Jensen and Kletzer (2005) use a Gini-coefficient for geographical concentration to measure how tradable a service is. The higher the concentration the higher is the degree of tradability. They create three groups from highly concentrated to least concentrated. Unfortunately their categorisation of industries is based on 2-digit North American Industry Classification System (NAICS), which is not comparable to the UK SIC and therefore cannot be used for the BSD.

This selection is conducted at the firm level. Therefore we only keep firms which are part of one of the industries from the list above. The selection of local units is not affected, therefore a manufacturing firm can still have a local unit in the wholesale sector. Why was only the tradable service sector for firms chosen, which is only a small part of the total service sector? The common definition of services is based on 1993 System of National Accounting (SNA) and is as follows: "*Services are not separate entities over which ownership rights can be established. They cannot be traded separately from their production. Services are heterogeneous outputs produced to order and typically consist of changes in the condition of the consuming units realised by the activities of the producers at the demand of the customers. By the time their production is completed they must have been provided to the consumers.*"[76] This definition fits to the theoretical concept of non-tradable service sector. The Manual on Statistics on International Trade in Services points out that there are industries regarded as service industries, where the border between goods and services is blurring, which leads to the concept of tradable services. For example, the storage of information (R&D), consultancy reports (software consultancy) etc., enables services being kept in physical assets, which qualifies the definition just mentioned.[77] This storage possibility also increases the complexity of services provided. This complexity is required to provide fragmentation opportunities. For example, a firm in the R&D sector (tradable) will require computers and machinery for experiments, specialists from the IT sector, etc. IT services can maybe sourced internally and computers and machinery from an outside supplier. A firm in the industrial cleaning sector (non-tradable) will be simplistic with a rather short production chain. It will be unlikely that this firm will own a detergent producing plant. Data proves that we hardly find any vertical linkages in the non-tradable service sector. Therefore we will focus only on the

[76] See UN et al. (2002), pages 7*f*.

[77] Even though the concept of tradable and non-tradable services is intuitive, the application of this classification for industries is less clear. Harris and Li (2006) show that even non-tradable service firms can be exporters. For example, in 2004 4.8 percent of firms of the Hotels & Catering sector and 8.3 percent of the Retail Trade sector are exporter.

more interesting case of the tradable service sector.

Another category we will not analyse consists of industries which cannot be uniquely allocated to tradable or non-tradable services. For example, "wholesale trade" has characteristics of both classifications. A wholesale business does not have to be located next to its customers and is preferably located where there is enough space for storage. But if it is too remotely located customers have to face additional costs, therefore transport costs are still significant. Another unclassified industry is transportation. Again there is not a clear line and the theoretical models may not apply for these firms.

These subsamples need further cleaning because of the massive outliers in the tradable service sector mentioned on page 75. The turnover figures are driven by some extreme outliers, where an unrealistic increase in turnover is followed by a decrease back to the level previous periods. This can be caused by errors in entering those turnover figures in the BSD. The consequence is an unstable and unreasonable picture of the UK corporate landscape. Several cleaning methods have been tried, but the best result was achieved by dropping the extremely volatile sectors with unreasonable turnover changes. So the analysis will still be representative for the remaining industries. All financial intermediation sectors (SIC 65 and SIC 67), insurance services (SIC 66) and management activities of holding firms (SIC 74.15) are excluded from analysis. Another solution was to drop all the firms of the top 0.5 percent with regards to their turnover. Even though many firms are still kept in the sample the total number of people employed per industry and total industry turnover was reduced significantly.[78] Because the BSD enables a representative analysis for the UK, dropping all big firms would be not desirable.[79]

[78]Results for this sample is provided in the appendix on pages 275*ff.*

[79]Another selection method was tried where the sample was first divided into "regular" firms and "large" firms which belonged to the biggest ten percent of firms. If an enterprise switches from a regular to a large firm and the change was caused by an increase or decrease by a factor equal or greater than ten, then that company was dropped. Unfortunately this method could not clear the erratic results, because of two reasons: On the one hand, some companies have been confronted by large changes, but have always been part of the large sample and therefore could not been dropped. On the other hand, it is less likely for a large company to double or triple its turnover temporarily for a year than for a small company. So a doubling of a large company's turnover for one period could be already a

In the manufacturing sector one outlier was dropped. The omitted firm experienced an unrealistic increase in local units. Some companies report zero turnovers for the whole observation period and are therefore regarded as dead companies. We drop those firms. Table 3.14 shows the differences between the number of local units and enterprises for each sector before and after cleaning the data from outlier industries and firm outliers.

		Manufacturing		**Tradable Services**	
	Year	full	clean	full	clean
Enterprises	1997	162,357	159,401	356,896	299,299
	1998	162,437	161,701	391,801	339,754
	1999	157,562	157,013	414,666	363,462
	2000	148,055	147,548	429,245	378,593
	2001	145,977	145,479	442,996	391,474
	2002	142,729	142,141	450,316	397,179
	2003	137,903	137,365	454,537	402,219
	2004	133,619	133,220	483,750	429,603
	2005	129,427	129,106	514,104	458,257
	2006	126,099	125,763	547,045	489,681
	2007	125,035	124,679	580,362	520,929
	2008	123,916	123,555	609,120	547,899
	Total	1,695,049	1,686,971	5,674,838	5,018,349
Local Units	1997	184,613	181,603	412,660	319,862
	1998	183,059	182,318	448,264	360,903
	1999	177,755	177,194	471,860	384,467
	2000	167,214	166,701	485,430	399,021
	2001	164,496	163,991	502,567	411,714
	2002	160,582	159,988	507,196	416,814
	2003	154,333	153,834	516,272	428,137
	2004	149,475	149,072	542,718	455,346
	2005	144,634	144,309	574,606	483,257
	2006	141,332	140,509	615,874	522,818
	2007	140,089	139,240	653,939	556,728
	2008	138,568	137,748	665,586	565,218
	Total	1,906,150	1,896,507	6,396,972	5,304,285

Table 3.14: Sample size before and after cleaning per sector

The careful reader will realise that only 12m out of 24m firms of the sample after the first cleaning are left. The difference is explained by unclassified service sector firms,

potential outlier but would not be recognised by the selection rule.

firms in the agricultural sector, dropped outliers and companies which are changing their industry.

3.4.2. Inconsistent variables

To make the BSD consistent over time some amendments are needed.

Industry Classification: The format of the SIC is changing over time. Sometimes the variable is saved as a number and sometimes as a string. Furthermore some industries are miscoded as 4-digit code in 1997 and 2008. Industries affected are 01, 02 and 05, because for those two years the leading 0 is missing.

Reference Numbers: Usually reference enterprise and enterprise group reference numbers are stored as a number. In 1999 those reference numbers are stored as a string and have to be transformed into a number.

Postcode: The presentation of the local unit and reporting unit postcode varies. To create a consistent postcode the separation of the postcode into two parts has to be removed. For example, instead of "NG7 2RD" "NG72RD" is created.[80] This cleaning is only required if analysis is conducted at the VML.

Foreign Ownership: The foreign ownership variable contains a country code, which changes three times over time. For example, in 2008 the numeric code was swapped for a two letter code abbreviation. Therefore I created a new variable which only shows if the owner is foreign or domestic.

Death Code: The way the death code is stored changes between being a number and being a string.

[80] This postcode is just an example and has not been selected from the BSD.

3.4.3. Missing local unit information

As briefly mentioned above, information is missing for local units between 1998 – 2004, especially in 2003. Table 3.15 shows how severe the problem is. To mitigate this problem data has to be imputed for the local unit industry classification, the local unit postcode and the enterprise reference number of a local unit. The imputation rule was that if data is missing in period t, it will be identical to those from the period $t-1$ but only if the observations of $t-1$ and $t+1$ are available and identical. Table 3.15 illustrates how this intervention improves the situation.

	entref		**lu sic**		**lu poco**	
	raw	*cleaned*	*raw*	*cleaned*	*raw*	*cleaned*
1998	62,006	14,606	62,042	19,495	62,006	17,134
1999	42,888	31,888	42,928	33,660	42,888	34,268
2000	57,597	47,497	58,158	49,415	57,605	50,115
2001	75,406	63,685	75,830	65,864	75,409	66,378
2002	84,032	69,495	84,347	74,011	84,032	72,695
2003	199,607	54,670	200,036	70,706	199,607	64,328
2004	34,135	21,431	34,395	24,153	34,135	25,025

Table 3.15: Missing variables of local units, before and after cleaning

3.5. Notable Changes Over Time

Significant changes have happened over the twelve year time period from 1997 – 2008 in the UK. In total, the number of firms increased by 19 percent, but a different development can be observed in different sectors. The manufacturing sector is shrinking, with regards to number of firms, local units and employment. Only nominal turnover is increasing, which indicates that labour productivity has increased significantly over time. A different pattern can be observed in the tradable service sector, where the number of firms, local units, employment and turnover is increasing massively. A common pattern is that the share of single-plant firms to total firms is increasing. While multi-plant firms are getting bigger in terms of employment and turnover, the percentage increase of nominal turnover is much lower for single-plant firms. Furthermore single-plant firms employ fewer workers over time.

As chapter 4 will reveal, vertically integrated companies seem to allocate their local units in 2008 further away than in 1997. We find also an increase in the degree of fragmentation in the manufacturing and tradable service sector, which is driven by the large increase of single-plant firms.

3.6. Differences Between BSD and ARD

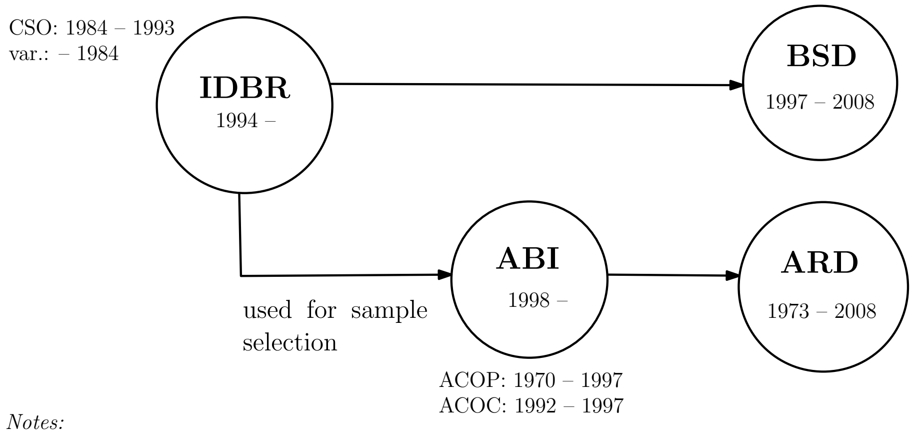
Besides the BSD, the second large enterprise database of the ONS is the Annual Respondents Database (ARD). While the former contains a major part of UK enterprises and local units, the latter one contains detailed information for a selected sample of UK firms.

They are similar in that respect that both databases are based on the IDBR, which has already been explained above. While the IDBR is directly used for the BSD, it has two purposes for the ARD. Firstly, it is needed for sample selection in the ARD (ONS, 2002a). The firms are not selected from a representative sample. While all large firms are part of the sampling fraction, it is only 25 percent of the small firms.[81] As part of the Annual Business Inquiry (ABI) questionnaires are sent to selected firms which have the mandatory duty to answer them. The information of the ABI is the main source of the ARD.[82] Figure 3.2 summarises the differences. Secondly, it provides basic information on non-selected or non-responding firms, which will be discussed below.

The ARD contains only data from the production sector until 1992. From 1993 onwards

[81] Large firms are firms with an employment of more than 250 and small firms with less than 10. There are different sample fractions for firms between this range, depending on the industries. See ONS (2002a), page 22.

[82] Before 1998 the Annual Census of Production (ACOP) from 1970 – 1997 and the Annual Census of Construction (ACOC) from 1992 – 1997 was used instead of the ABI. See ONS (2002a), pages 16*ff*.



Notes:
ACOC: Annual Census of Construction
ACOP: Annual Census of Production
ABI: Annual Business Inquiry
ARD: Annual Respondents Database
BSD: Business Structure Database
CSO: Central Statistic Office Business Register
IDBR: Inter-Departmental Business Register

Figure 3.2: Differences between ARD and BSD

the construction sector was added. The sample size of selected firms is between 13,000 and 23,000 until 1996. From 1997 onwards the service sectors have been added, which more than doubled the sample size to around 50,000 (Robjohns, 2006). From 2000 also parts of the primary sector (SIC 02 and SIC 05) have been added (ONS, 2002a, p. 20). In comparison to that the BSD contains a couple of million more observation, but only from 1997 onwards and only basic information about employment, turnover, industry and location. Note that merging the selected and non-selected sample of firms of the ARD gives almost all the information available in the BSD, except turnover for companies not selected for the ABI, and who provide this data to the HMRC. For the selected sample the ARD provides 700 variables (Robjohns, 2006, p. 47). This allows us to create complex variables like capital stocks for industries, which requires different types of capital expenditures and which should be weighted using the full ARD population.

Another difference is that the main level of analysis in the BSD is the local unit and the enterprise level, and in the ARD it is the reporting unit level. Also the date of recording is different. While the BSD data is from March, the ARD provides data from the calendar year, but firms *"may report on any other 12 month period up to the end of the financial year"* (ONS, 2002a, p. 18). The observation period of the BSD is from 1997 – 2008 and for the ARD 1973 – 2008.

Concluding, for our analysis on fragmentation based input-output measures, the BSD provides all the necessary information. For using other measures, like value added to sales ratios, the Annual Respondents Database (ARD) should be used.

3.7. Conclusion: Use of the Data for Research on Fragmentation

The most important advantage of the BSD is that it covers the population of UK firms which have employees or whose turnover exceeds the VAT threshold. This provides us with sufficient observations for analysis of certain events which may be relatively uncommon (such as selling off vertically integrated local units). Enterprises can be easily linked to local units and to other databases which is, as it will be shown in chapter 5, very useful for the analysis of fragmentation. The BSD contains precise information about the activity of a firm and local units, the exact location through an eight digit postcode, and is therefore a useful instrument for the analysis of fragmentation. The possibility of merging with the Office for National Statistics Postcode Directory enables the researcher to measure the distance between headquarters and local units. The merger with ONS input-output tables reveals vertically linkages between local units of a company. Besides static analysis about the degree of vertical integration and the distance between headquarters and vertically integrated local units, the panel structure of the BSD enables a dynamic analysis, so existing companies can be followed over time.

A drawback is the inconsistency of the enterprise group reference number. For fragmentation decision other firms of the same enterprise group can affect the fragmentation decision of a company. The comparison of the enterprise and enterprise group level could have been of interest but only a minor sample can be used. Furthermore, because of its inconsistency, it is impossible to follow enterprise groups over time.

Another issue is that no information exists on foreign affiliates. It can be the case that a company is vertically integrated, but, because the plant is located in another country, this company will not be recognised as vertically integrated. Because the number of firms, which actually set up a plant abroad, is relatively low, not too many firms should be wrongly classified.[83]

Even though there are some drawbacks with the data, the detailed information, accuracy and the possibility to merge the information with other databases of the ONS will give interesting insights into fragmentation decisions of companies.

[83]See page 101 for a quick review about how many firms are actually involved in foreign activities.

4. Are UK Firms Becoming More Fragmented?

As early as 1937 Coase's celebrated article asked the question: "where are the borders of a firm?" When is it better for a firm to buy inputs from the market and when is it better to create a contractual relationship to produce the intermediates internally? If parts of the required intermediate inputs are sourced from the market, we will refer to this firm to be organisationally fragmented.[84] If production stages are spread over different locations it will be referred to as spatial fragmentation. Currently we live in a world of outsourcing[85] but some commentators argue that increased fragmentation is not inevitable. For example, Santander returned call centres from India to the UK (The Independent, 2011) because of customers who were unhappy with the service provided. In this chapter we want to show how important fragmentation has become for UK firms and if we can observe a trend reversal recently or not. A comprehensive theoretical literature exists to describe why firms are out- or insourcing and is discussed in chapter 2. The empirical literature is focused on international fragmentation, because moving production parts abroad is a source of concern for the domestic population.

The evidence of international fragmentation is straight forward. Campa and Goldberg (1997) and Feenstra (1998) find evidence for an increase in international fragmentation of firms. But as Brainard (1997) points out, the data to measure international activity is often limited. For example, Feenstra and Hanson (1997) use the share of intermediate inputs to total intermediate inputs. No differentiation between outsourcing and FDI can be made. This can be crucial because moving a production stage abroad, but keeping the ownership affects the organisational structure of a firm differently than buying intermediates from a foreign market. Even if FDI flows can be identified there is still a lack of information. The distinction between vertical FDI, which is related to fragmentation, and horizontal FDI is important, because the theoretical foundation of each type is dif-

[84]See page 9 for the precise definition of fragmentation.
[85]This is often critically viewed by the public, see for example The Telegraph (2002, 2005).

ferent. Another problem is the lack of detailed information about the location of foreign affiliates. In general, only the country of residence is known. This can create misleading results, because two domestically linked firms might be further away from each other than domestic headquarters to its foreign affiliate.[86] All those concerns are crucial for the analysis of fragmentation of the production chain.

A clearer picture about the degree of vertical integration is provided by firm level studies looking at fragmentation of domestic firms. Maddigan (1981) finds an increase in the degree of vertical integration between 1947 – 1972, but the small sample size of less than 100 firms might not be representative. Kim (1999) shows that the share of multi-plant local units in the US manufacturing sector increased from 7.4 percent in 1919 to 21.9 percent in 1987. This implies that US firms became geographically more dispersed and, if the multi-plant local units are producing intermediate inputs, more vertically integrated. In contrast to this, Abraham and Taylor (1996) report an increase in outsourced services for US manufacturing firms between 1979 – 1986/87. Girma and Görg (2004) get similar results for the UK. The outsourcing intensity is increasing for the electronics and mechanical engineering sectors between 1980 – 1992 and for the chemical industry between 1989 – 1992. Holl (2008) reports an increase in subcontracting by Spanish firms between 1990 and 1999. Those studies use rather small samples of the manufacturing sector or focus on only certain industries. For example, Abraham and Taylor (1996) use mainly firms with more than 100 employees, but the great majority of firms are much smaller than this. Therefore those results may not be representative.

A way to create a more accurate picture of the change in the organisation structures of firms is by using the Business Structure Database (BSD) of the Office for National Statistics (ONS). It will be possible to see if the average UK firm is sourcing more or less intermediate inputs internally and if they source from more dispersed regions or

[86] It is a significant difference if a German affiliate of an Austrian company is located in Munich or in Hamburg.

not. The BSD contains a five digit SIC code for companies and local units to enable the identification of horizontally and vertically linked affiliates. Furthermore, eight digit postcodes make an exact localisation of local units possible.

The drawback of this database is that it only allows us to identify domestic organisational structures. However, the International Sourcing Statistics (ISS) database of Eurostat and a dataset presented by Tomiura (2009) provide evidence that the majority of firms do not source internationally. The former is a representative sample of big firms with more than 100 employees of any sector. Even of large UK firms 63 percent are not sourcing internationally and are not planning to do so.[87] According to Eurostat the results for the UK are overstating the real amount of international sourcing.[88] Those figures do not differentiate between foreign sourcing through foreign affiliates or foreign market transaction. Tomiura (2009) shows, for the Japanese manufacturing sector, that 0.2 percent of firms are outsourcing only abroad, 2.5 percent abroad and domestically and 46.5 percent only domestically in 1998.[89] Those results fit to the theoretical models of heterogeneous firms like Melitz (2003), where only a small number of companies will engage in international fragmentation. Even though only few firms source internationally, it does not imply that imported intermediate inputs are negligible. UK input-output tables from 2005 show that 16.6 percent of intermediate inputs used have been imported. Because our analysis is focused on the firm level,it is expected that important facts about fragmentation can be gained, even though transport costs or cultural differences may only have a little impact on domestic fragmentation.

[87] The data was collected by National Statistical Institutes over the period 2001 – 2006. A survey was sent to companies with more than 100 employees. No clear information has been given if all firms have replied or not in the UK. Firms from the financial intermediation sectors were excluded. The sample size was 7,174 enterprises.

[88] See Euro-SDMX Metadata Structure, available at `http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/EN/iss_esms.htm`, access on 09/02/11.

[89] The sample size consists of 118,300 firms. Tomiura (2009) uses a different definition of outsourcing, so not every market transaction is regarded necessarily as outsourcing. The Japanese firm structure is different to British enterprise groups. Many huge enterprise agglomerates exist in Japan, called *Keiretsu*, which makes the results comparatively lower to the UK. However, not all Japanese firms are included, which might lead to an upward sample selection bias.

The research question of this chapter is:

How fragmented are UK firms, and has the degree of fragmentation changed over time?

At the time of writing, this chapter represents the most detailed and comprehensive study of the organisational structure of UK firms, and the first to analyse changes in organisational structure over time. The BSD allows us to extend the focus from the manufacturing sector to the service sector. The main results are that not only the importance of the sectors, but also that the average size of firms has changed significantly. The degree of vertical integration was rather low and decreased over time in every sector. A decomposition of the change reveals that the decrease is mainly caused by new firms rather than by continuing firms. With regards to spatial fragmentation, UK firms, which are vertically integrated, became more dispersed. We conclude that intermediate inputs are sourced from more distant locations. Newly vertically integrated firms are the reason for the increase in the dispersion of firms.

The chapter will be structured as followed: *First*, the sample used will be described. *Second*, a general picture of the UK company landscape will be drawn to see how the importance of different industries has changed over time. *Third*, a baseline measure of fragmentation will be presented. Are more firms becoming multi-plant firms? In how many different regions are those multi-plant firms located? In the *fourth* part the static analysis of fragmentation is discussed. Here the measures of organisational and geographical fragmentation will be explained. *Finally*, in the last section, the dynamic analysis will be conducted.

4.1. The Sample

In chapter 3 a comprehensive description of the BSD is provided.[90] The majority of fragmentation studies focus on the manufacturing sector, but, as it will be shown below, the service sector has become more and more important. Therefore the sample is divided into two sub-samples, namely the manufacturing and the tradable service sector. This classification is based on GATS mode of transportation classification, where for the tradable service sector the proximity to the final customer is negligible (for example a call centre). The classification is as follows:

- **Manufacturing**: SIC 15 – 37
- **Tradable services**:
  - **SIC 72**: Data processing and software consultancy (excl. SIC 72.5)
  - **SIC 73**: Research and development services
  - **SIC 74**: Business Services (excl. SIC 74.15, SIC 74.6 and SIC 74.7)

There are several reasons for expanding the analysis by the service sector. Manufacturing firms and service firms differ significantly from each other (see section 4.2). It is assumed that the decision about fragmentation is based on different determinants affecting service and manufacturing firms differently. The reason why only the tradable service sector is considered is that the non-tradable service sector is not suitable for the analysis of fragmentation. Non-tradable services have in general a rather short production chain leaving fewer possibilities for fragmentation. This is illustrated by the fact that there are only few massive firms (such as large retail firms) which are vertically integrated, but in general, most multi-plant firms are not integrated. In addition, the geographical distribution is driven by proximity to the market rather than the drivers of fragmentation

[90]Besides the BSD also other datasets like the Financial Analysis Made Easy Database (FAME), the National Statistics Postcode Directory (NSPD) and input-output tables are employed. A brief description of those sources can be found in the appendix on page 266.

discussed in Chapter 2. A precise description of the sample is provided in section 3.4.1. Table 4.1 reveals the sample which will be used in this chapter.

	Manufacturing		**Tradable Services**	
Year	Firms	Local Units	Firms	Local Units
1997	158,092	173,239	340,416	367,210
1998	160,425	174,096	381,831	409,505
1999	155,726	168,991	405,140	431,471
2000	146,282	158,355	419,640	444,970
2001	144,234	155,728	433,398	457,499
2002	140,924	152,217	440,389	462,827
2003	136,249	146,544	446,379	467,119
2004	132,100	141,992	475,504	495,422
2005	128,055	137,273	505,674	524,271
2006	124,758	133,476	538,439	557,031
2007	123,710	132,337	571,958	591,717
2008	122,612	130,878	599,964	619,933
Total	1,673,167	1,805,126	5,558,732	5,828,975

Table 4.1: Sample size after second cleaning process

4.2. The UK Manufacturing and the Tradable Service Sector

One unique feature of the BSD is that it offers information about the manufacturing and the service sector. The importance of the service sector has significantly increased, especially if employment and turnover figures are considered. We will focus only on the tradable service sector.[91] In the following we illustrate how those two sectors have developed over time and evidence is given for the increasing importance of the service sector.[92]

As a first measure the total number of firms and local units will be considered and

[91] See page 88 for a further discussion why this classification has been chosen.

[92] One problem with the Industry classification is that it is often difficult to find the border line between manufacturing and services. The classical differentiation between manufacturing as a process where raw materials are transformed into finished products is not appropriate anymore. Livesey (2006) mentions IBM as a company producing computers turning into a “service manufacturer”. After selling the PC production to Lenovo, the main source of income is through services. A problem can arise if the share of manufacturing and service activities is about the same size, then the classification just into manufacturing and services can be too crude.

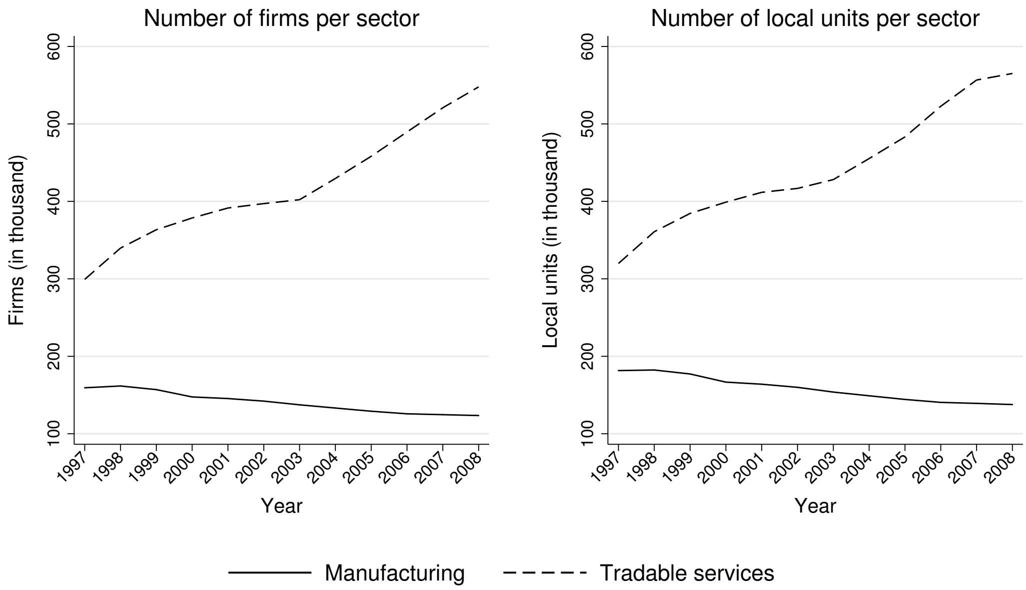


Figure 4.1: Size of sectors according to number of firms and local units

graphically illustrated in figure 4.1. The development over time looks rather similar for firm and local unit figures. A massive change has happened over the time period from 1997 – 2008. The number of manufacturing firms shrank by 27 percent but the number of tradable service firms increased by 83 percent.

Those developments can also be observed with other size measures, like total employment and total turnover per sector. Figure 4.2 captures those variables. Employment and turnover figures are increasing in the service sector. Real total turnover[93] in the tradable service sector nearly doubled and employment rose from about 2m to 3m. The opposite is happening in the manufacturing sector. Employment in manufacturing decreased massively, from 3.8m down to 2.5m.[94] Total turnover decreases until the end of the 1990s until 2005 and remains approximately constant afterwards.[95]

[93]We use the OECD GDP deflator with base year 2000.
[94]According to ONS (2008) the employment figure for manufacturing industries was about 2.9m in 2008.
[95]In the appendix on page 268 the same graph is included with the sample including all outlier industries. This picture supports the decision, why financial services have been dropped from analysis.

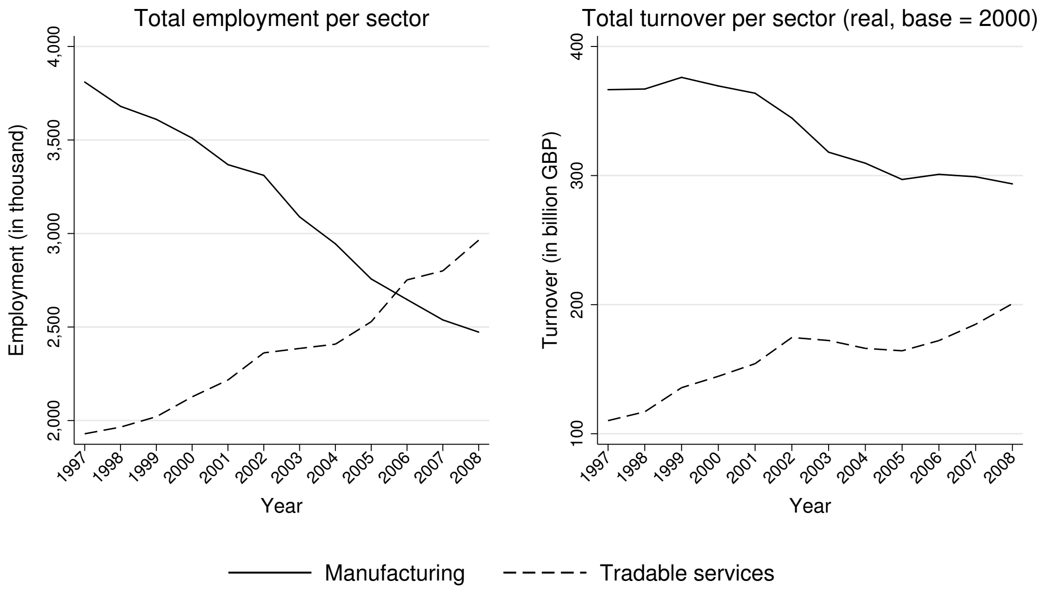


Figure 4.2: Size of sample sectors according to employment and turnover

The development of both sectors is different. How did the average firm change over time? As shown in figure 4.3, manufacturing and service firms differ massively from each other. Manufacturing firms are characterised by higher turnover and employment rates. The mean manufacturing firm had 24 people employed in 1997 but only 20 in 2008. In the tradable service sector it decreased from 6.4 down to 5.5. There is less variation in the median size of firms. The median manufacturing firm had 4 employees in 1997 and 3 in 2008. The median tradable service firm had 2 employees in 1997 but only 1 in 2008, which is extremely low. We can speculate that this fall in employment could be the first evidence for organisational fragmentation. The mean turnover did not change much in manufacturing and in the tradable service sector. The median turnover is much smaller. While we find a small increase in the median real turnover in the service sector (from £63.5k to £67.5k) it decreased in manufacturing (from £183k to £153k). The massive decrease in average firm employment and an approximately constant mean turnover rate implies that labour productivity increased significantly. This would be the result we

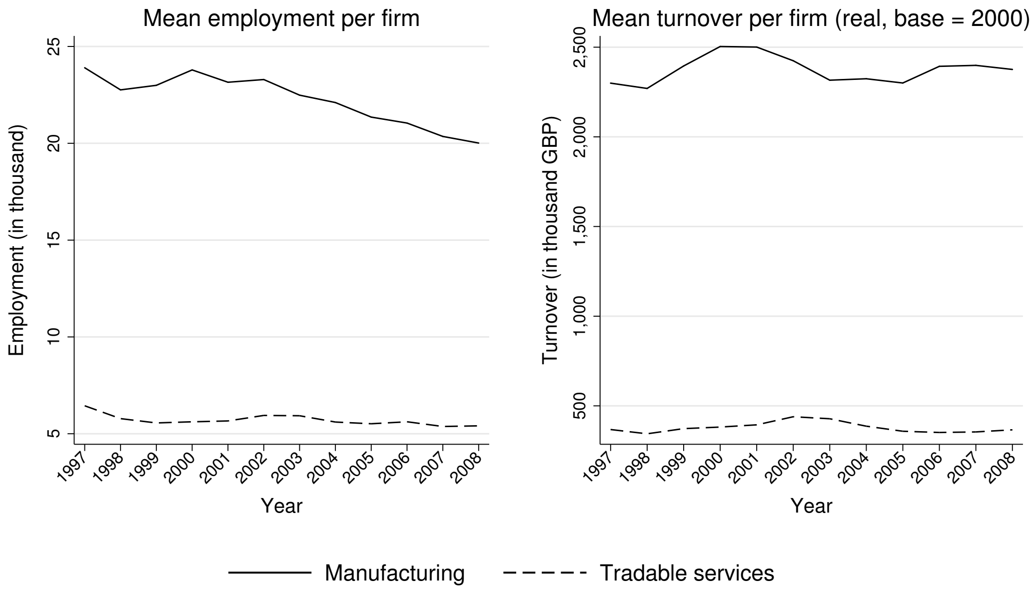


Figure 4.3: Changes in the size of firms according to mean employment and mean turnover

expect, because fragmentation means that firms specialise in their core activities and productivity has therefore to increase. Even though a total factor productivity (TFP) measure would be more suitable, we can only use labour productivity measures for this thesis, because of the available information in the BSD. Empirical evidence shows that capital deepening was responsible for a large share of labour productivity growth in the late 1990s (Nordhaus, 2002, p. 236). That means the actual "specialisation" effect may be overestimated. We will conduct further investigations below to see if our first impression of increased fragmentation can be confirmed.

Foreign ownership became more important in every industry, but especially in the manufacturing sector. At the beginning of the observation period until 2004, foreign ownership information is missing for some observations, so it might be the case that the increase in foreign ownership is less/more dramatic. See graph 3.1 on page 85 for more detailed explanations.

A huge change has happened in the last twelve years. The tradable service sector now dominates the manufacturing sector in terms of number of firms, employment and turnover. Firms have become smaller in terms of employment, while at the same time having constant or increasing turnover.

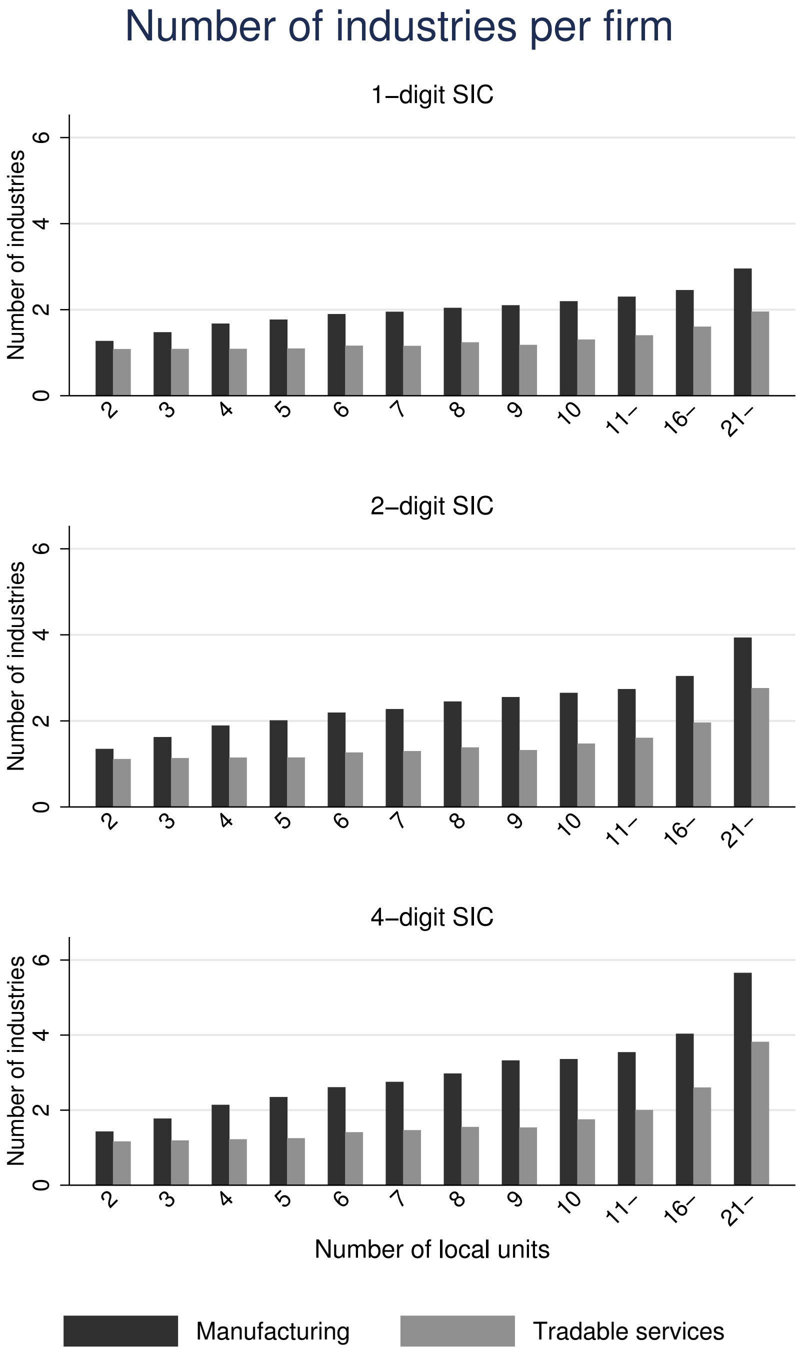
4.3. A Baseline Measure of Fragmentation

In this section we provide two baseline measures of fragmentation. The first organisational fragmentation measure looks at how many intermediate inputs are sourced from outside suppliers and the second geographical fragmentation measure looks at how dispersed UK firms are.[96]

A necessary condition for a firm to be vertically integrated is that it produces different products. Figure 4.4 captures how many plants a firms has, which are part of a different SIC sector.[97] The main activity of a local unit is recorded and categorised according to SIC 03. We cannot observe if a local unit is also performing other minor activities.[98] In our sample only multi-plant firms can be multi-product firms. Because of confidentiality rules of the ONS, companies with more than ten local units have to be grouped together. The presented SIC codes are at the 1-digit, 2-digit and 4-digit level. The more local units a company has, the higher the amount of activities will be.

Figure 4.4 reveals an important fact: In general, manufacturing firms are active in more industries than service firms, regardless of the SIC aggregation.[99] Firms of the service sector are, even if they are active in different four digit industries, mainly based in the same one digit industry, with the exception of firms with more than 20 local units. The explanation for this pattern is that the production of services is fundamentally different

[96] A more detailed explanation is provided on page 9.
[97] The median values are similar, therefore we present only the mean values.
[98] See page 83 for a detailed description of how activities of firms and local units are identified.
[99] We use SIC 03 for classifying each firm. However, using SIC 03 could be a potential source of underestimating the degree of heterogeneity. The change from SIC 03 to SIC 07 introduced a finer classification of services revealing that tradable services are not as homogeneous as used to be presumed. Still, the total number of 4 or 5 digit SIC industries is lower for tradable service sector in comparison to the manufacturing sector. See ONS (2009b).



Note: On the x-axis the number of local units a firm owns and on the y-axis in how many different 1, 2 or 4-digit SIC sectors the local units are active are presented. Firms with more than 10 local units are aggregated into three groups: 11-15, 16-20 and more than 20 local units. The bars show how many local units of a different SIC code level the mean firm with a specific number of local units owns.

Figure 4.4: Mean number of industries per firm pooled over period 1997 – 2008

from the production of manufacturing goods. While the production of a manufacturing good requires other goods and services, the production of services requires mainly other services. This has the following consequences: On the one hand, we expect more firms to be vertically integrated because of more possibilities to integrate production stages. On the other hand, the location decision of manufacturing and tradable service firms will be different.

How geographically dispersed are these firms? This question is answered by figure 4.5. The postcode information of the BSD identifies the location, where four different levels of regional aggregation have been used. The full postcode is, for example, "NG7 2RD"[100], the postcode district is "NG7" and the postcode area is "NG". The highest level of geographical fragmentation is captured by government office regions, for example, "East Midlands".

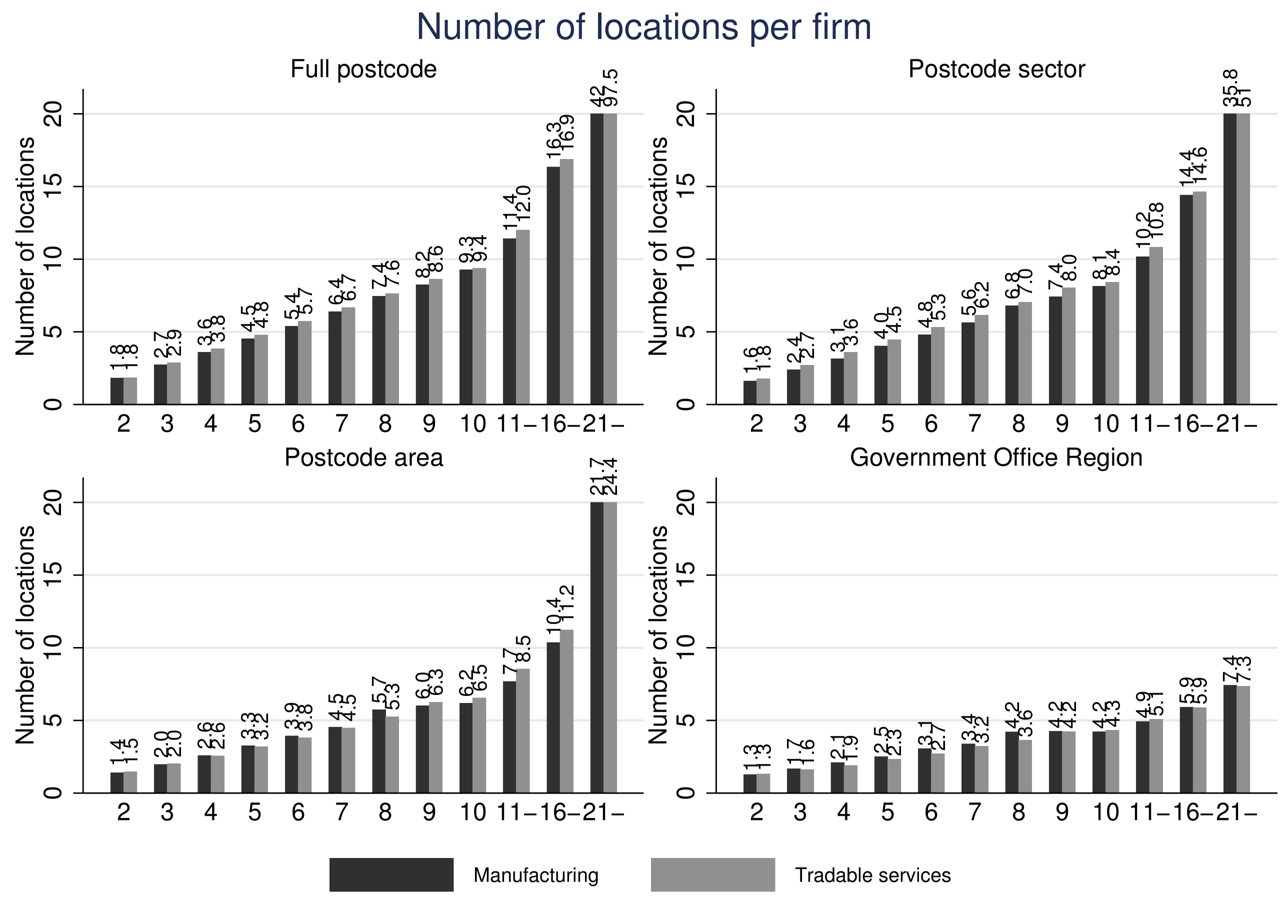
Because the largest firms with more than twenty local units are significantly more dispersed, the bars have been censored at twenty locations. Using median values does not change the picture, therefore we stick to the mean values. At the full postcode level, not many differences exist between manufacturing and the service sector with the exception of the largest companies. The location data shows that the biggest tradable service firms are much more dispersed (98) than manufacturing firms (42). Those numbers include horizontally and vertically linked local units. The higher the aggregation level, the smaller are the differences between manufacturing and service sector firms. If only government office regions are considered then the differences of the largest firms disappear completely — all large firms are acting nationwide. Surprisingly, the spatial distribution of manufacturing and tradable service firms is quite similar. We would have expected manufacturing firms to be more dispersed. Because the location of local units can be driven by the input factor prices, plants of manufacturing firms might be located in areas with a relatively low property price and headquarters are located in areas where

[100]This postcode is random and has not been identified from the BSD.

sufficient services are supplied, for example, in cities. At a first glance the tradable service sector looks different to what was expected: the nature of tradable services should support concentration and not dispersion to enjoy economies of scales. One reason is that in graph 4.5 only multi-plant firms are included. But as shown in figure 4.6 the number of multi-plant firms is significantly lower in the tradable service sector than in manufacturing. It is less likely for tradable service firms to become a multi-plant firm but if they become one, they have local units in different regions. Another interesting fact is that the number of multi-plant firms is decreasing in every sector, which is a first indicator of firms becoming more organisationally fragmented over time.

A more precise measure of geographical fragmentation can be created by measuring the actual distance between all local units and their headquarters. We assume that the postcode of the reporting unit is similar to the postcode of the headquarters or at least to the largest local unit of the firm. Even if local units and headquarters are in the same region, it is possible that the distance between those is greater than if they were located in different regions (for example the distance between two local units in Derbyshire and Nottinghamshire can be closer than the distance between two local units within Nottinghamshire). Figure 4.7 shows the median distance for different firm sizes. We can see that in general the median manufacturing firm is more dispersed than a tradable service firm. This is what was expected, because service should be located in more agglomerated areas.[101]

[101] The differences are less severe if we look at the mean values, but still remain. A similar graph with mean values is located in the appendix on page 268.



Note: On the x-axis the number of local units a firm owns and on the y-axis the number of different locations at the full postcode, postcode sector, postcode area and government office region level of its local units are presented. Bars are censored for firms with more than 20 local units. The bars show the number of local units at different locations the mean firm of with a specific number of local units owns. The number at the top of the bars shows the actual mean value for the number of locations for each number of local unit cohort.

Figure 4.5: Number of locations per firm pooled over period 1997 – 2008

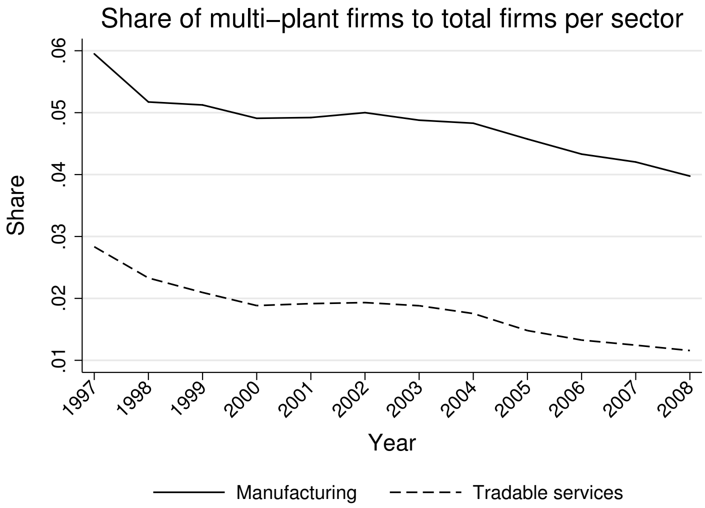


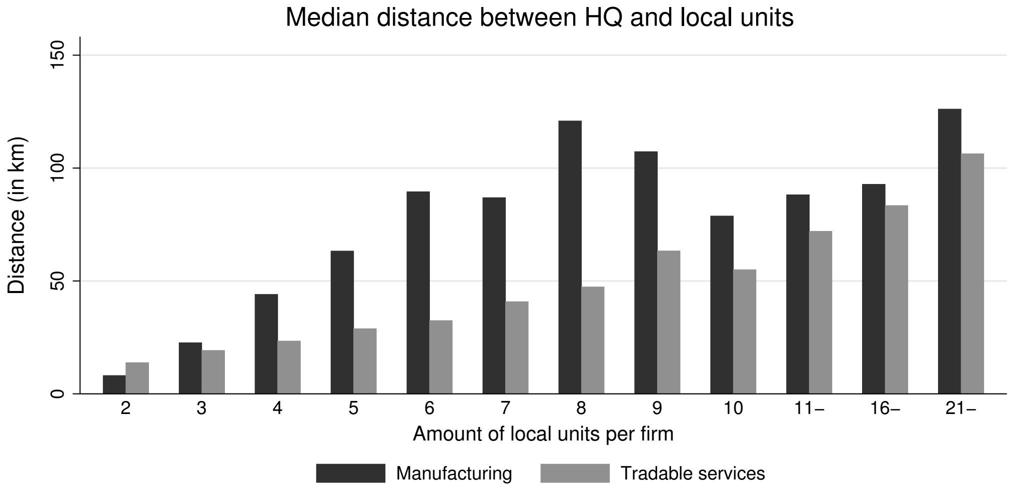
Figure 4.6: Share of multi-plant to total number of firms

4.4. A Static Analysis of Fragmentation

The baseline analysis is not sufficient for the analysis of the fragmentation of firms. On the one hand, no differentiation between vertically and horizontally linked local units was made. For fragmentation the vertical link is crucial. On the other hand, the number of industries a company is in does not say much about regarding the degree a company is vertically integrated. This section will take account of those aspects. A static analysis is conducted to create a comprehensive picture of how fragmented UK firms are. This section does not deal with the mechanics behind changes. Those will be part of the dynamic analysis.

4.4.1. Organisational fragmentation

The baseline measure purely looked at how many different products a company is producing. This does not imply that all products are intermediate inputs for other production stages. Furthermore it does not give information about the importance of a product in the production chain. In this section a measure of vertical integration, which is the



Note: On the x-axis the number of local units a firm owns and on the y-axis the distance between local units and the reporting unit of a firm are presented. We assume that the address of the reporting unit is similar to the address of the HQ. The bars show the median distance between local units and HQ which belong to firms with a specific number of local units. This graph takes account of horizontally linked and vertically integrated local units.

Figure 4.7: Median distance between headquarters and local units

opposite of organisational fragmentation, will be created and analysed. This section is heavily based on the approaches of Davies and Morris (1995) and Acemoğlu et al. (2010).

A measure of vertical integration

Many studies have been published with an empirical measure of vertical integration (see section 2.1.4) but most of those measures are rather problematic. One of the main problems is that the derivation of the measures requires additional company and industry information, which is often unavailable. Many of the studies mentioned in section 2.1.4 using a classical vertical integration measure suffer from a relatively small sample, because precise data about turnover, market shares and value added are often only available for large companies. In contrast, the information needed for the calculation of the vertical integration measure employed here is rather modest. The intermediate input structure from input-output tables, the number of plants per firms and the SIC code of all local units are sufficient. Furthermore, the measure features the distinction between forward and backward vertical integration and is always between zero and one. The focus of our measure lies on the local unit and the firm level.

A plant is *backward* vertically integrated when another plant belonging to the same firm exists which is producing intermediate inputs required by the first plant. For example, a firm possesses a plant producing cars and another plant producing steel. The car plant requires steel as intermediate inputs, which is supplied firm internally. Therefore the car producer is backward vertically integrated. A plant is *forward* vertically integrated when another plant belonging to the same firm exists which requires the intermediate inputs produced by the first plant. In the example just mentioned the steel producing plant would be forward vertically integrated.

Before we can derive and interpret the measure we have to state the following assumptions:

1. All companies in the same industry have the same intermediate input structure.
2. The output of a local unit is sufficient to satisfy the demand of the upstream local unit, so, for example, bi-sourcing cannot exist.
3. If a local unit is producing intermediate inputs for another local unit, then all of its output is traded internally.

Assumption 1 is similar to Maddigan (1981), who assumes that the same technology is prevailing for all companies within the same industry. This is a good approximation for companies offering homogeneous goods. For companies in a differentiated goods sector the input structure can be quite different, for example, a car producer can decide to use mainly steel for safety reasons for the production of a car and another one might prefer plastic parts to reduce the production costs. Because of *assumption 2* all intermediate inputs produced internally are enough to satisfy the demand of the company. Acemoğlu et al. (2010) show that this assumption may not be far-fetched. Their calculations suggest that if a firm has an intermediate input supplying plant it will be enough to satisfy the demand for this specific intermediate input of the downstream firm. On average, if a vertical linkage between local units of different industries belonging to the same company exists, 93 percent of the demand for intermediate inputs is satisfied by internal production.[102] Finally, according to *assumption 3* all goods are traded internally, for example bi-sourcing cannot arise. Because of this all forward vertically integrated units are by definition fully integrated. Therefore only a vertical integration dummy for forward integration can be generated.[103]

Our measure of backward vertical integration is calculated for a local unit as shown in equation 4.1:

$$vib_{li} = \sum_{j=1}^{R} a_{kj} \times I_{ij} \tag{4.1}$$

where l is a local unit, i is the company that local unit l is part of, a_{kj} indicates the proportion of inputs demanded by a local unit of industry k from a supplying industries j (technology coefficient), and I_{ij} is a dummy vector which is 1 if company i has another local unit in a sector j or 0 otherwise. vib_{li} is therefore the share of total intermediate inputs used by local unit l of company i which are provided by other local units of company i. If $a_{kj} > 0$, where $j = k$, observations will only be kept in the sample if there are other local units of the same company with a different 4 digit SIC code. For example, a solicitor office is part of 4-digit SIC code 7411. If there are several offices with the same owner and the same SIC code, but at different locations, those observations will be treated as not vertically integrated. If it has another office which is responsible for bookkeeping activities, the 2-digit SIC code would be the same (74), but they will differ at the 4-digit level (7412). This company has a positive degree of vertical integration if $a_{74,74} > 0$.[104]

[102] Acemoğlu et al. (2010) highlight that this does not imply that all demanded intermediate inputs can be provided internally. See page 50 equation 2.9 for how Acemoğlu et al. (2010) calculate this value.

[103] With the input-output tables it is possible to calculate the share of outputs of a local unit a of industry j delivered to another local unit b of industry k. Because of assumption 3 the degree of forward vertical integration will always be one for a.

[104] Note that input-output tables are relatively aggregated, therefore a identification of how many goods

The measure of backward vertical integration at the enterprise level is the average value of the degree of vertical integration of all local units l of company i.

$$vib_i = \frac{\sum_{l=1}^{n} vib_{li}}{n_i} \tag{4.2}$$

where n_i is the number of local units within company i and vib_{li} the degree of vertical integration of the local unit. vib_i is the average share of backward vertical integration of local units within company i.

Because of assumption 3, another approach has to be taken to calculate the forward vertical integration measure at the local unit level. Only a forward vertical integration dummy can be created.

$$vif_{li} = \begin{cases} 0 \ldots \text{if firm } i \text{ does not own a plant in ind. } j \text{ supplying its plant in ind. } k \\ 1 \ldots \text{if firm } i \text{ owns at least one plant in ind. } j \text{ supplying its plant in ind. } k \end{cases} \tag{4.3}$$

The enterprise level measure will also be a dummy as shown in equation 4.4:

$$vif_i = \begin{cases} 0 \ldots \text{if } \sum_{l=1}^{n} vif_{li} = 0 \\ 1 \ldots \text{if } \sum_{l=1}^{n} vif_{li} \geq 0 \end{cases} \tag{4.4}$$

If firm i has at least one plant which is vertically integrated the whole firm will be regarded as vertically integrated. We use a similar method for the derivation of the backward vertically integration dummy.

The following example illustrates the logic behind the measure. On the left hand side of table 4.2 a made-up *Use* input-output table can be found. The demand of different industries for certain goods is listed in the columns and goods produced, which are

from sector 7412 are actually used in 7411 is not possible. We only have information about how many goods from sector 74 are demanded by sector 74. Therefore if the firm owns those two affiliates, then $a_{7411,7412} = a_{74,74}$.

comparable to supplying industries, are listed in the rows. In this example only ten different goods are produced in the economy. Cell (1,1) shows that 30 percent of all intermediate inputs demanded by industry 1 are supplied by industry 1, 10 percent by industry 2, 20 percent by industry 3, etc.

IO-table					**BSD**			
goods | ind.	1	…	3	…	entref	luref	ind	vi_b
1	0.3	…	0	…	A	01	1	0.35
2	0.1	…	0	…	A	02	3	0.7
3	0.2	…	0.5	…	A	03	3	0.7
4	0	…	0	…	A	04	7	…
5	0.1	…	0	…	A	05	10	…
6	0.1	…	0	…	⋮	⋮	⋮	⋮
7	0	…	0.1	…				
8	0	…	0	…				
9	0.05	…	0.3	…				
10	0.15	…	0.1	…				
Sum	1	…	1	…				

Table 4.2: The calculation of a vertical integration measure using input-output tables

On the right hand side of the table is a synthetic example of the BSD. *entref* is an abbreviation for enterprise reference number, *luref* is for a local unit reference number and *ind* indicates the industry that each local unit is part of. Enterprise A owns five plants, which are part of four different industries, 1, 3, 7 and 10.

We compute[105] if any of the plants of enterprise A are supplying intermediate inputs demanded by the plant concerned. For example, plant 01 is active in industry 1. In the input-output table we have the information about the share of intermediate inputs demanded by industry 1. 10 percent of the intermediate inputs demanded are supplied by industry 2. Firm A does not have any plants active in industry 2, therefore we can conclude that those 10 percent of intermediate inputs demanded by the local unit have to be sourced from the market. The next industry in the input-output table is industry

[105] We provide the code in the appendix on pages 269*ff* and explain the syntax.

3, which supplies 20 percent of intermediate inputs for industry 1. This time firm A owns local units (02 and 03) of industry 3, therefore we assume that at least 20 percent of intermediate inputs are produced internally. This process continues for all industries. Local unit 5 of firm A is active in industry 10, and is therefore another intermediate input supplier for local unit 1. 15 percent of intermediate inputs demanded by industry 1 come from industry 10. Therefore local unit 01 will end up with a degree of vertical integration of 35 percent.

The same procedure is applied for all other local units. A special case arises for local units 02 and 03, which are of the same industry. According to the input-output table half of the goods demanded are supplied by its own industry. Only if both plants are of different 4 digit SIC industries vertical integration is recorded. In the example both plants are in different 4-digit SIC industries and therefore have to be taken into account for the degree of vertical integration (which is 70 percent for plants 02 and 03).

Our vertical integration measure is closely related to the Davies and Morris (1995) and Acemoğlu et al. (2010) measures but differs in certain aspects:

- **Level of aggregation**: Davies and Morris (1995) provide a firm measure and Acemoğlu et al. (2010) is creating a within-firm measure, where the degree of vertical integration is calculated for industry pairs of its local units. For one local unit several vertical integration measures exist. For example, a steel producing plant requires inputs from three industries: coal, iron ore and chemical sector. Therefore three degrees of vertical integrations are derived. If the steel producer also owns a plant in the chemicals sector, then the degree of vertical integration for the steel-chemicals industry pair would be positive and for the steel-coal and steel-ore pairs equal to zero. The measure of this work is based on the local unit level, through which the firm level can be calculated.

- **Precision**: Davies and Morris (1995) and Acemoğlu et al. (2010) use additional information to improve the precision of their measure. Davies and Morris (1995) include the market share of a company to separate the internal intermediate input flows from intermediate inputs delivered to outside firms. This measure is not able to distinguish between backward and forward vertical integration. Besides the market share also total sales of a company are needed for the calculation. A more precise measure is used by Acemoğlu et al. (2010). By using information about the value of intermediate inputs produced and needed for the production of the final product, Acemoğlu et al. (2010) can exactly tell what share of intermediate inputs is supplied internally. The used measure in this work treats all firms equally, so the actual amount of intermediate inputs supplied internally cannot be considered.
- **Time Period**: In contrast to Acemoğlu et al. (2010), who are using cross section data, Davies and Morris (1995) and I look at time series data.

The measure faces certain limitations. One issue with all input-output table based measures is that outside factors exist which can influence the technology coefficient even though the actual technology has not changed. For example, regulations could alter prices of intermediate inputs. This affects the value of intermediates supplied by one industry to another industry and can change the relative composition of the intermediate input structure, even though no actual change in the intermediate input structure has happened. Nevertheless the degree of vertical integration may change.

Secondly, they often take account of only direct not indirect linkages between plants. Assume a simplified diamond production chain illustrated in figure 4.8. Three production stages exist, mining, manufacturing and retailing. Additionally there are three local units called A, B and C, where A is in the mining business, B in manufacturing and C in retailing. All of them are vertically linked with each other. A does not need any other intermediate inputs, B only requires inputs of plant A and C sources all its input from

Production chain in diamond industry

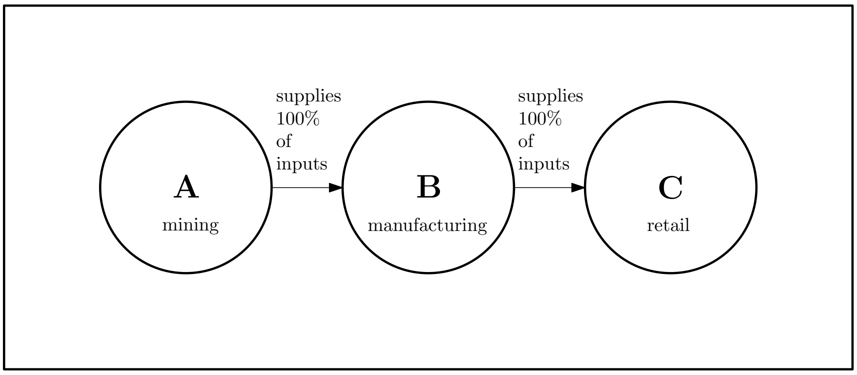


Figure 4.8: Illustration of problems caused by indirect linkages for the vertical integration measure

B. So the whole production process of C consists of three production blocks. If C does not own any other company the vertical integration measure will be zero. If C buys B, the manufacturing company, then C will have a degree of backward vertical integration of 1, even though it does not own the first production step. To pursue the problem further, if C owns A, but not B then C would not be regarded as vertically integrated, even though A is part of the production process. The measure may overvalue (scenario 1) or undervalue (scenario 2) the actual amount of vertical integration

Finally, our measure can only capture vertical integration, if a separate local unit exists which produces intermediate inputs. A firm producing final products and intermediate inputs within one establishment will not be recognised by our measure.

Nevertheless, despite these drawbacks, our measure is suitable for our analysis. Other measures often require detailed balance sheet information and therefore only a few firms can be used for analysis. One aim of this chapter is to find out how the *average* UK firm has changed. Even though our measure is less precise than comparative measures, we can calculate the degree of vertical integration for every firm in our sample. A straight forward interpretation, a distinction between forward and backward vertical integration[106] and

[106]This distinction can be important, for example in chapter 5 the backward measure is preferred, but in chapter 6 we require the forward measure.

the possibility of calculating a firm level measure support the choice of our measure.

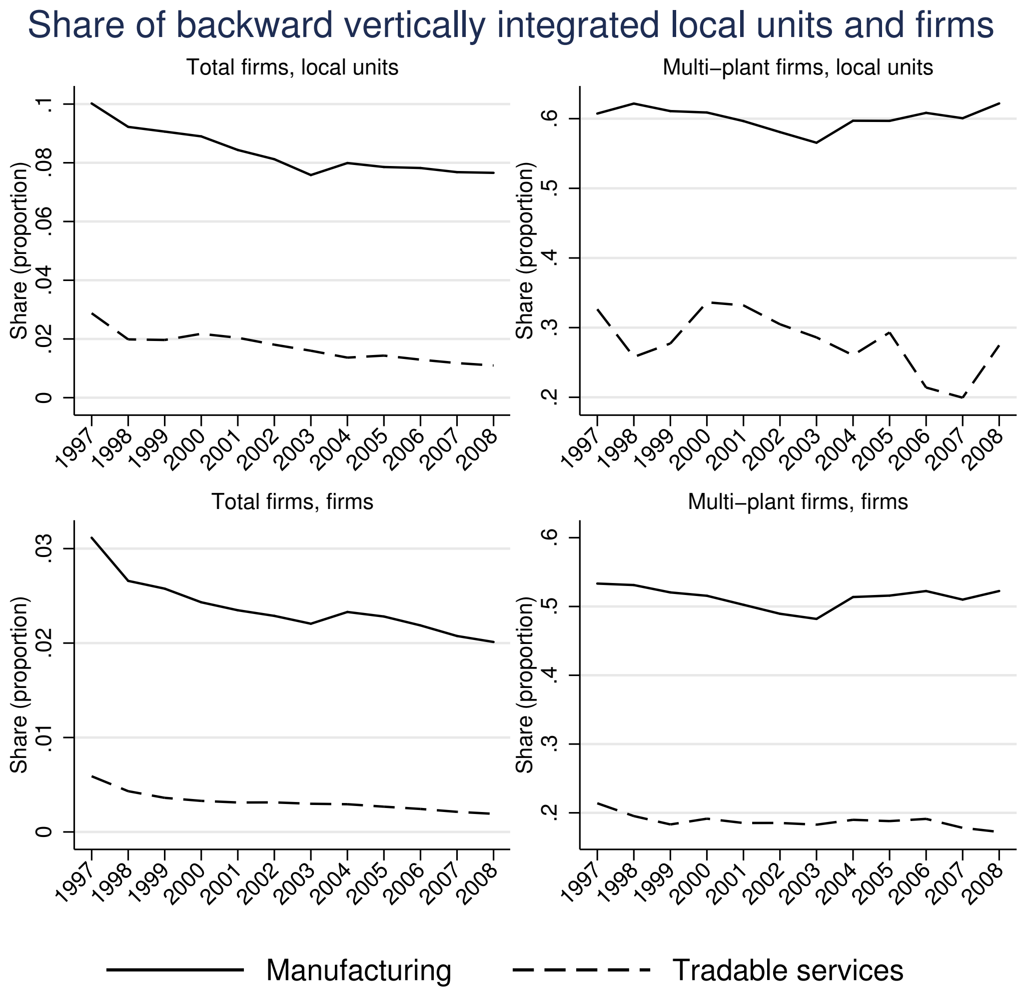
Empirical evidence for vertical integration

After showing how important vertically integrated firms are for both sectors, the change in the degree of vertical integration over time will be analysed for the backward integration sample.

Firstly, we show in graph 4.9 how many firms are backward vertically integrated. We do not present the graph capturing the forward sample, because the development of the share of forward and backward integrated firms and local units is similar.[107] The top two panels show the share of vertically integrated local units to all local units if all firms (top left) or only multi-plant firms (top right) are considered. In the bottom the share of vertically integrated firms to all firms (bottom left) and vertically integrated firms to multi-plant firms (bottom right) are captured.

The following discussion will be based on the backward sample. The share of vertically integrated firms and local units is much lower in the tradable-service sector than in manufacturing. The share of vertically integrated firms to all firms is significantly lower than the share of vertically integrated local units to all local units. In the manufacturing sector, the share of vertically integrated local units decreased from 10 percent to 7.6 percent for the whole sample. The multi-plant sample shows a relatively constant share that was always around 61 percent. This picture is supported by the firm measure. If all firms are considered, then the share decreased from 3 percent to 2 percent. The share of the firm multi-plant sample was always around 52 percent. There was a decline in every share and every measure for the tradable service sector. The already low share of vertically integrated local units decreased further from 2.9 percent to 1 percent (all firms) and from 32.6 percent to 27.4 percent (multi-plant firms). At the firm level the picture is similar, the share decreased from 0.6 to 0.2 percent (all firms) and from 21.4

[107] The share of forward and backward vertically integrated *firms* are even identical.



Note: All four panels show the share of backward vertically business units based on different samples. The top left panel includes the share of backward vertically integrated local units to all local units keeping all firms. The top right panel shows the share of backward vertically integrated local units to local units of multi-plant firms only. The bottom left panel contains the share of backward vertically firms to all firms and the bottom right panel the share of vertically integrated firms to multi-plant firms only. This graph does not contain any information about the degree of vertical integration of firms and local units.

Figure 4.9: Share of backward vertical integrated local units and firms according to type of firm

percent to 17.2 percent (multi-plant firms). Concluding, the share of vertically integrated firms decreased, regardless of the sector. In the next paragraph we analyse how many intermediate inputs are sourced internally.

The measure described in section 4.4.1 is used to find a quantitative measure of vertical integration. The measure points in the opposite direction of fragmentation, that means that the lower the degree of vertical integration is, the higher is the degree of organisational fragmentation. A firm with a degree of zero is completely fragmented and with a degree of one it is completely vertically integrated. The main input for this measure is the use of the input-output table from 2002. The ONS offers annually updated input-output tables, but because of the following reasons I only use one.[108] On the one hand, input-output tables should not change dramatically over years. On the other hand, changes in the input-output tables can be caused by outside factors which can influence the intermediate input structure even though the actual technology has not changed. For example, regulations could alter prices of intermediates. This affects the value of intermediates supplied by one industry to another industry and can change the relative composition of the intermediate input structure, even though no actual technological change in the intermediate input structure has happened. Nevertheless the degree of vertical integration may change over time. If just the input-output table of 2002 is kept, those problems can be avoided.

By keeping the limitations of the vertical integration measure in mind, figure 4.10 shows how many of the intermediate inputs are sourced within the firm. Four different graphs are gathered. In the first one in the top left panel the degree of vertical integration for the average UK firm is calculated. In the top right graph the degree of vertical integration for the average multi-plant firm, in the bottom left for firms with more than ten local units and in the bottom right for all vertically integrated firms are presented. We only present

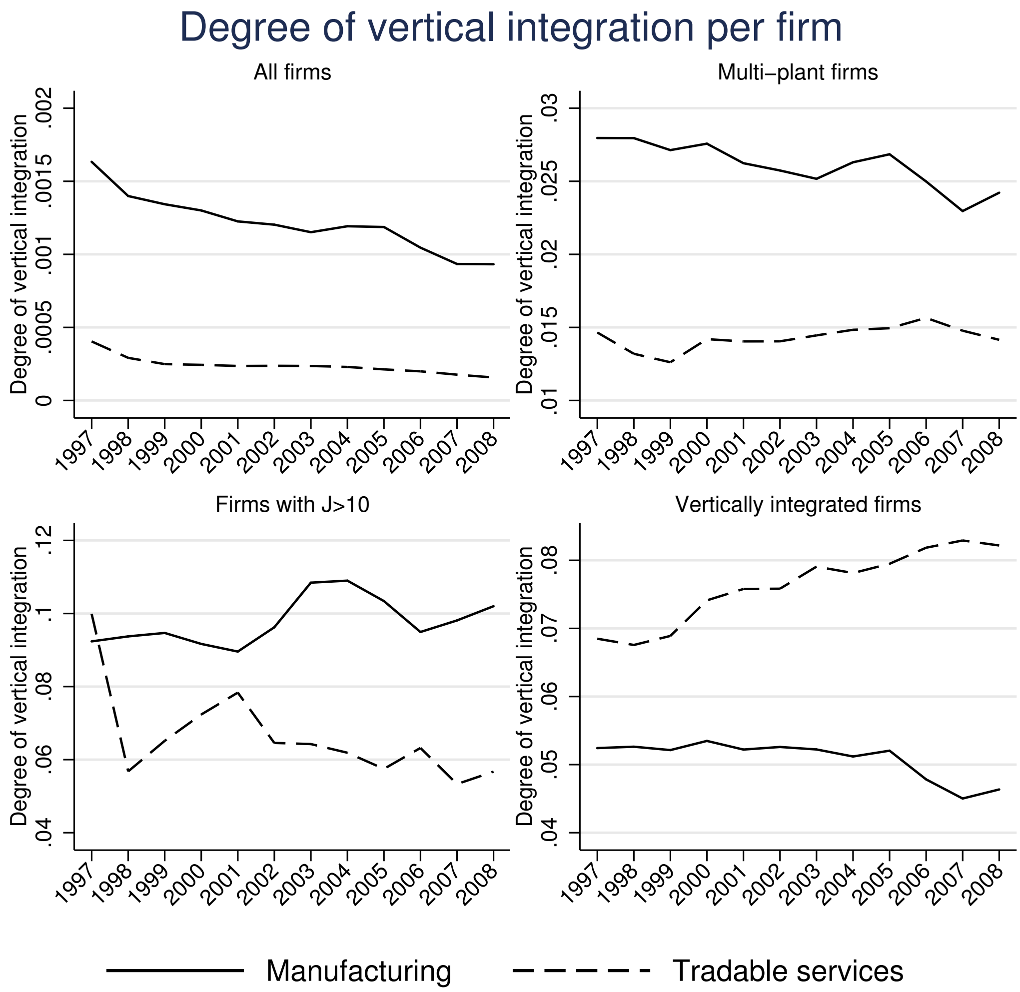
[108]It has been checked if the results will change if the input-output tables from 1997 are used. As it can be seen on page 272 in the appendix, the results have not changed significantly.

the firm and not the local unit measure. The latter one is too erratic in the tradable service sector. Therefore we move this measure to the appendix on page 274 with an explanation, what is causing these fluctuations. The average degree of integration of a local unit within a firm is not confronted with his problem. The results are presented in figure 4.10.

The measure of vertical integration is extremely skewed. The median firm was not vertically integrated, regardless of the sector. In manufacturing, the average (mean) degree of vertical integration of a firm decreased from 0.16 to 0.09 percent, but also if only multi-plant firms are considered, the degree decreased from 2.8 to 2.4 percent. Only the largest firms became more integrated (from 9.2 to 10.2 percent). The average degree for vertically integrated firms declined too (from 5.2 to 4.6 percent).

The degree of vertical integration for all tradable service firms decreased from 0.04 to 0.016 percent. The degree for the multi-plant sample was with 1.4 percent rather constant and decreased strongly from 1 to 0.57 percent in the sample with firms with more than ten local units. It was less likely for local units in the tradable service sector to be vertically integrated in comparison to the manufacturing sector, but if they are vertically integrated they will be at a higher degree. The degree increased for vertically integrated firms from 6.8 percent to 8.2 percent.

This section reveals that the majority of firms are not vertically integrated. Even if only vertically integrated firms are considered, the degree of vertical integration is low. This is in accordance with other studies using input-output measures for measuring the degree vertical integration (see section 4.6 on page 140). The average vertically integrated manufacturing firm does not produce more than 5 percent and the average vertically integrated tradable service firm more than 8 percent of its intermediate inputs internally. This implies that a very large share of supply for the average firm comes from outside. The second new finding is that the average UK firm became more fragmented between



Note: All four panels are based on equation 4.2 which presents the degree of backward vertical integration at the firm level. The top left panel shows the average degree of vertical integration of all UK firms (including single plant firms). The top right panel shows the average degree of backward vertical integration if only multi-plant firms, the bottom left panel if only firms with more than 10 local units and the bottom right panel if only vertically integrated firms are kept.

Figure 4.10: Degree of vertical integration per firm according to type of firm

1997 – 2008. We will discuss possible explanations for these findings after conducting the dynamic analysis.

4.4.2. Geographical fragmentation

A measure of spatial fragmentation

As for organisational fragmentation, a discrete and continuous measure will be presented. The first measure is a multi-location dummy. If a firm has at least one local unit in more than one region, then the multi-location dummy will be one. The calculation is described in equations 4.5 and 4.6 and based on Landier et al. (2009), with the difference that we only look at vertically integrated local units.

$$ML_{ir}^{vi} = \begin{cases} 1 \ldots \text{ if } (\sum_{l=1}^{n_l} lu_{lir}) > 0 \text{ and } vi_{lir} > 0 \\ 0 \text{ otherwise} \end{cases} \tag{4.5}$$

$$ML_{i}^{vi} = \begin{cases} 1 \ldots \text{ if } (\sum_{r=1}^{n_r} ML_{ir}^{vi}) > 1 \\ 0 \text{ otherwise} \end{cases} \tag{4.6}$$

where the index i represents the firm, l the local unit and r the region. lu_{lir} is a dummy which is one if firm i has a local unit l in region r. Equation 4.5 identifies if local units in different regions exist. Because we focus on fragmentation only vertically integrated local units are considered. If firm i has at least one vertically integrated local unit in region r, then the multi-location firm region dummy will be one. In the second stage (equation 4.6) all those multi-location firm region dummies are added up and if there are local units in more than one region, the multi-location firm dummy will be one.

Another way to calculate the spatial dimension of fragmentation is to measure the distance between the headquarters of a firm and its intermediate input supplier.[109] Unfor-

[109] Alternatively, Audia et al. (2000) are measuring the average distance of all local units with each other.

tunately, it is difficult to gain information about the location of unaffiliated intermediate input suppliers. This data does not exist in the UK.[110] We therefore focus on the dispersion of vertically integrated firms.

To measure the distance between the headquarters and its vertically integrated affiliates we use the NSPD.[111] This database links every postcode of firms or plants to unique coordinates, called Eastings and Northings. The concept of Eastings and Northings can be illustrated by putting a grid over the UK. One point of the grid regards as starting point. All postcodes can be reached by an Eastings-Northings vector, which is measured in meters. The earth curvature is ignored[112], therefore the distance between two postcodes can by derived by using Pythagoras' theorem, like in equation 4.7:

$$dist_{il} = \sqrt{(North_i - North_{il})^2 + (East_i - East_{il})^2} \tag{4.7}$$

where the postcode of firm i equals the postcode of the headquarters of the firm, l is one local unit of firm i and $North$ represents Northings and $East$ Eastings.[113] In contrast to the general indicator of fragmentation mentioned in section 4.3, not the distance between all local units but only between vertically integrated local units and their headquarters are considered. Equation 4.7 is the foundation for our firm dispersion measure presented in equation 4.8.

$$av.\ dist_i = \frac{\sum_{i=1}^{n_i} \overbrace{\left(\frac{\sum_{l=1, l \neq i}^{n_{il}} dist_{il}}{n_{il}} \right)}^{\text{av. distance within firm}}}{n_i} \tag{4.8}$$

[110] To illustrate it with table 2.1 on page 11, it is partly possible to differentiate between the cells in the right column, but not for the two cells in the left column. Only the geographical distance between the affiliates of the same company can be identified.

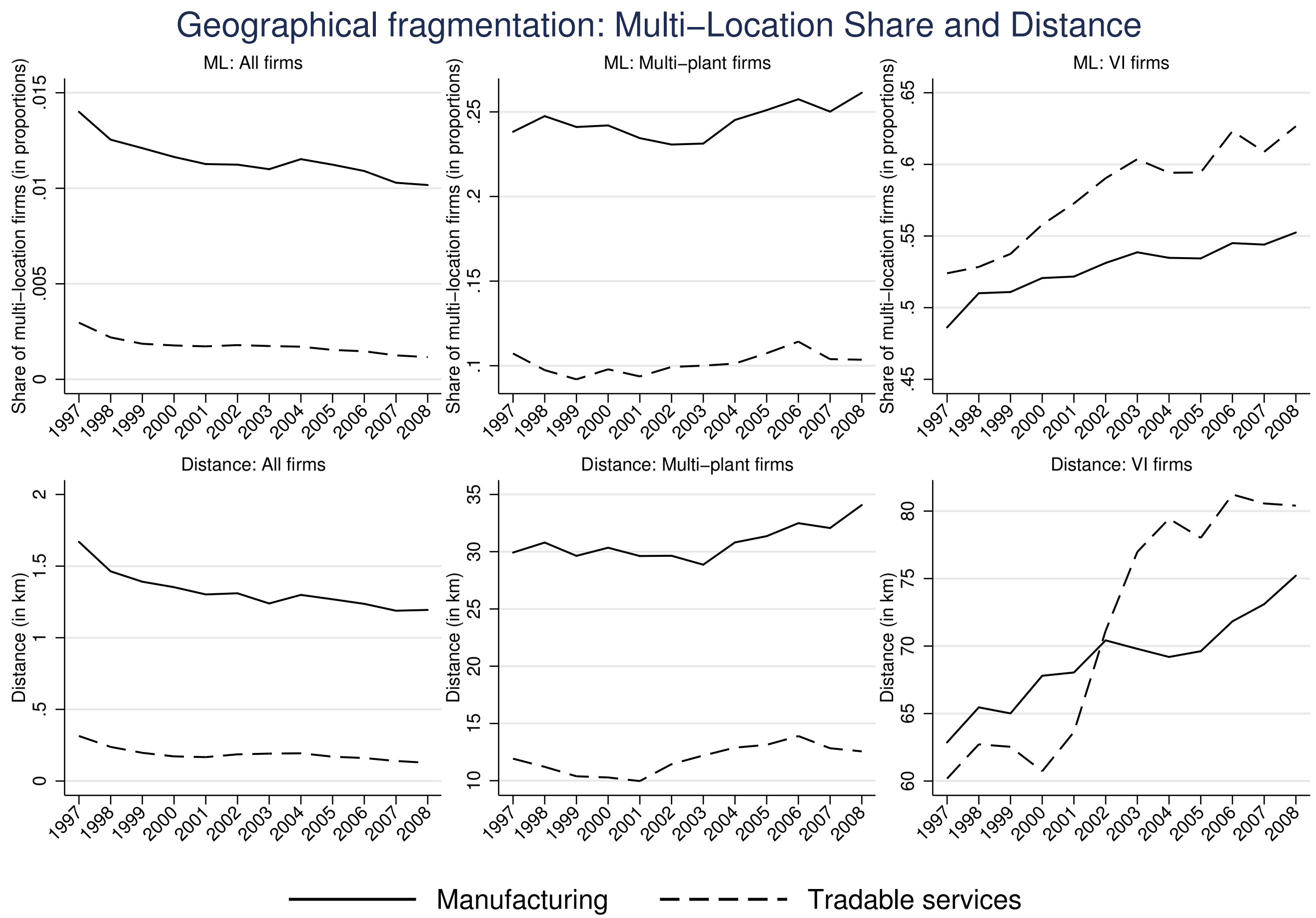
[111] The National Statistics Postcode Directory of 2009 is used.

[112] According to Duranton and Overman (2005) ignoring the earth curvature in the UK leads only to a maximum possible error of one kilometre, which is negligible.

[113] Information about firms and local units in the BSD are provided by reporting units. A reporting unit is a local unit, providing the information. As we show on page 79, our assumption that the location of the reporting unit is equal to the location of the headquarters is valid.

where i is the index for firms and l for local units. We calculate first the average distance between the headquarters and its local units within every firm and then create an average distance over all firms of the sample. Graph 4.11 reveals the results for the multi-location and mean distance share. We present here the results for the multi-location dummy and distance by using *forward* vertically integrated local units. Even though the results hardly change, it is from a conceptual point of view more appropriate to look at local units, which are producing intermediate inputs than at local units which are receiving intermediate inputs. The total share of multi-location firms is decreasing in both sectors. The share of multi-location firms decreased from 1.4 to 1 percent in manufacturing and from 0.3 to 0.1 percent in the tradable service sector. If we consider the share of multi-location firms to all multi-plant firms, the share is with 25 percent in manufacturing and 10 percent in the service sector rather constant. The important result appears in the last graph of the first row. The share of multi-location units to all vertically integrated local units is increasing strongly. While 49 percent of vertically integrated firms in manufacturing and 52 percent in the service sector were multi-location firms in 1997, it increased to 55 percent and 62 percent respectively.

In the second row of figure 4.11 we show the distance measure. We can actually only measure geographical fragmentation for vertically integrated firms. For example, we cannot tell if single-plant firms are sourcing intermediate inputs from the same or from another region. If we just look at vertically integrated local units, we can get an idea, where the intermediate inputs producing plants are located. Therefore the graphs with the all firm and multi-plant firm sample are driven by the reduced number of vertically integrated firms.



Note: The top row shows the share of multi-location (ML) firms (measured at the postcode-area level), to all firms, multi-plant firms and vertically integrated firms. The bottom row shows the mean distance between forward vertically integrated local units and their headquarters within a firm using all firms, multi-plant firms or vertically integrated firms only.

Figure 4.11: Share of multi-location firms and mean distance of forward vertically integrated local units to their HQ within firms.

To analyse the change in geographical fragmentation we will focus on the last graph in the second row. The average distance is increasing from 63km to 75km in manufacturing and from 60 to 80 km in the tradable service sector.

To check if the way of calculation is valid, the reliability of reporting unit post codes has been analysed. By using the FAME database it is possible to identify if the postcode of headquarters is similar to the reporting unit postcode. The result for a sub-sample of the manufacturing sector was that for 84 percent the location was similar. See section 3.3 on page 79 for a precise description of this reliability check.

It can be concluded that vertically integrated firms are becoming significantly more dispersed over time, regardless of their sector. The distance measure indicates an increase in geographical fragmentation in manufacturing during the observation period of 1997 – 2008 by around 19 percent and the tradable service sector by 33 percent. The increase in geographical fragmentation can be based on several factors mentioned in section 2.1.2. According to the factor proportion theory and the Knowledge Capital Model the dispersion can be caused by an increase in factor price differences between different regions of the UK. Furthermore, a decrease in the costs of service linkages can reduce the barriers of fragmentation. It even can be an indicator that the costs of outsourcing decreased in comparison to setting up a vertically integrated plant. Therefore firms may shut down local units which are close to the headquarters, because factor-costs advantages are not large enough anymore. If that is the case we would expect firms, which become vertically integrated, to be more dispersed than old firms. To find support for that idea, we have to conduct a dynamic analysis.

4.5. A Dynamic Analysis of Fragmentation

While the static analysis is able to describe the current state of UK firms, it is not able to answer the question what the mechanism behind the change in the degree of fragmentation are. The picture from the static analysis stated above suggests that the average UK firm became organisationally more fragmented and the average vertically integrated firm spatially more dispersed. This could be caused by

1. new firms entering the market which are more fragmented,

2. old firms exiting the market which are less fragmented, or

3. existing firms becoming more fragmented.

The dynamic analysis reveals how firms change over time. Transition tables and decomposition methods are common tools to analyse the drivers behind changes. We will focus on decomposition. State transition tables show how many observations are changing their state over time, for example from the state of being vertically integrated to being fragmented. Firms hardly change their state from fragmented to integrated and vice versa, which can be an indicator that cause 3 is not the driving force behind fragmentation. Therefore the transition tables are only presented in the appendix on pages 278*ff*.

Decomposition is a useful tool for identifying the source of changes. It is very common in studies about wage differences to indicate the explainable and inexplicable part[114] or in papers about productivity growth to show what type of firms are causing it. The latter one is used as framework for the analysis of the change in the structure of organisational forms. Foster et al. (2006)[115] offer a method based on Baily et al. (1992), which is shown in equation 4.9.

$$\begin{aligned}\Delta F^o_{jt} = &\sum_{i\in C} s_{i,t-1}\Delta F^o_{i,t} + \sum_{i\in C}(F^o_{i,t-1} - F^o_{j,t-1})\Delta s_{i,t} + \sum_{i\in C}\Delta F^o_{i,t}\Delta s_{i,t} + \\ &+ \sum_{i\in N} s_{i,t}(F^o_{i,t} - F^o_{j,t-1}) - \sum_{i\in X} s_{i,t-1}(F^o_{i,t-1} - F^o_{j,t-1})\end{aligned} \tag{4.9}$$

[114] See for example Hisarciklilar et al. (2010).

[115] A more comprehensive description of different decomposition methods is available in Foster et al. (1998).

ΔF_{jt}^{o} is the change in a the degree of organisational or geographical integration ($o = \{org, geo\}$) of an industry j (manufacturing and tradable services) at time t. This change is generated by firms which are entering or exiting during the observation period and continuing firms, which have existed over the whole observation period.

The right hand side consists of variables at the industry (j) and firm (i) level. s_i is a weight representing the share of economic activity in a sector. For example, Foster et al. (2006) use man-hours at the local unit level, which was calculated by employment times industry average hours from the Bureau of Labour Statistics (BLS). We will use equal weights for every firm calculated as $1/(Number\, of\, firms)$. s_i does not measure in our case the share of economic activity but the firm concentration share. This can change over time, if more firms exit or enter the sector. Equal weights are not a drawback for the analysis because the focus of this research lies on how the average firm has changed over time and not on how the average output was produced. For example, consider an industry with few large integrated firms and many small fragmented firms. According to the output it might be the case that the average output is highly integrated because of the dominance of the few large firms. Still the average firms will be fragmented.

Continuing firms (C) can influence the degree of vertical integration in three ways: First, the firms can become more or less vertically integrated keeping everything else constant. It is ignored if the firm concentration has increased or not over time. This is measured by the change in the degree of fragmentation over time times the firm concentration variable in the starting period. The first term on the right hand side captures this effect, which is also called the *within* effect. The second term is called the *between* effect. It indicates how the change in the firm concentration affects the total change in the degree of vertical integration. If a firm with a higher degree of integration than the average firm experiences an increase in its firm concentration share, because many firms are exiting the sector, the overall change in F_{jt}^{o} will be positively affected. The last effect of continuing firms is a *cross* effect capturing how the change of the degree of integration affects the activity of a company. It is expected that an increase in fragmentation will lead to a decrease in the firm concentration share.

The first term in the second line of equation 4.9 captures the effect of entering firms (N). If a company enters which is more integrated than the average firm at the beginning of the observation period, then ΔF^o_{jt} will increase. The fifth and last effect comes from exiting firms (X). This time if an exiting firm is more integrated than the average firm then ΔF^o_{jt} will decrease.

4.5.1. Organisational fragmentation

The results for organisational fragmentation are presented in table 4.3 for the years 1997 and 2008. In the last column the absolute change of the degree of vertical integration is captured. The change is exactly the difference illustrated in figure 4.10. The degree of vertical integration decreased by 0.0007 in the manufacturing sector, which is a decrease of 44 percent in comparison to the degree of vertical integration in 1998 and by 0.00025 (-62.5 percent) in the tradable service sector. The values of the effects are all expressed in percentages. The sign for exiting firms has been changed according to formula 4.9.

	Continuing					
	Within	**Between**	**Cross**	**New**	**Exit**	*Total*
Man	21.3	-7.2	6.1	104.9	-25.1	-0.0007
Ser	3.4	3.4	-1.5	102.2	-7.5	-0.00025

Notes:
This table is based on equation 4.9. The last column (Total) shows the absolute change in the degree of vertical integration if all firms are considered. In all other columns (Within to Exit) values are in expressed in percentage. The first three columns (Continuing) show how much of the absolute change has been caused be continuing firms. The fourth column (New) indicates the influence of firms which entered after 1997 and the fifth column (Exit) the influence of firms which exited before 2008. A positive sign implies causing a decrease in the degree of integration and a positive sign an increase. We swapped the sign of the Exit column to be consistent with equation 4.9.

Table 4.3: Decomposition of the change in organisational fragmentation of firms

The degree of vertical integration is decreasing in the manufacturing sector, therefore all positive percentage figures mean a decrease in the degree of vertical integration. The main driver of the decrease in vertical integration is new firms (105 percent). The average firm, which entered between 1997 and 2008, was on average more fragmented than the average firm in 1997. Exiting firms were relatively more fragmented, but had a lower impact (minus 25 percent) than new firms. This can be caused by many small single-plant firms exiting the market. Around 20 percent of the change are explained by continuous firms, where the majority of the effect is caused by the within effect (21 percent). The average continuing firm became more fragmented (20 percent). The between effect shows in the opposite direction, leading to an increase in the degree of vertical integration.[116] The smallest effect is the cross effect capturing the interaction between the change in the market share and the change in the degree of vertical integration. Because continuing firms became more fragmented and less firms were in the market, the cross effect can only explain a small part of the increase in fragmentation.

In the tradable service sector the decrease in the degree of vertical integration is mainly caused by entering firms. 102 percent of the increase in fragmentation can be explained by those firms. The rest of the effects can only account for minor parts. Concluding, the main share of the decrease in the number of vertically integrated firms is caused by new firms, regardless the sector. We will discuss the implications of that result in the next section. Concluding, the decrease in the degree of vertical integration is mainly caused by new firms.

Implications of results

We can observe that the degree of vertical integration of the average firm and the average multi-plant firm is decreasing in manufacturing. This change is caused by new firms,

[116] This is exactly what was expected. The total number of firms is much lower in 2008. Therefore the market share of continuing firms will increase. A continuing firm is on average more vertically integrated than the average firm, therefore the increase in market share will have a negative effect on vertical integration.

which are mainly single-plant firms. Factors influencing the change in the degree of vertical integration will be discussed to a further extent in the next chapter. Some basic ideas will be presented here. As mentioned on page 90 one explanation why manufacturing firms are on average more vertically integrated is that the production chains are shorter for services. What is the reason for the decrease in the degree of vertical integration in all sectors and why is the decrease of different extent?

The main driver of the decrease in fragmentation is new firms. New firms generally start as single plant firms and are therefore regarded as fragmented according to our definition. What we show here is a structural change in the UK business landscape where the single plant structure seems to crowd out the vertically integrated multi-plant structure. But it is not just the case that the industry structure shifted, also characteristics of single plants have changed. We presented evidence that the average size of a UK firm is getting smaller between 1997 – 2008. These are patterns which can also be observed in other countries like Portugal, Denmark (Braguinsky et al., 2011) and the USA (Choi and Spletzer, 2011). We concluded that fragmentation can be the reason for this observable development, but there are other explanations as well. For example, in the case of Portugal, Braguinsky et al. (2011) blame strict labour market regulation, which do not allow firms to reach their optimal size, for firms getting smaller. Choi and Spletzer (2011) find that plant births are on average smaller and remain smaller in the following years than older firms. They conclude that a technological change has happened shifting production from labour intensive to more capital intensive production stages.

Even though new firms seem to be the main driver of fragmentation, the literature allows us especially to look at the change of continuing firms. Also continuing firms got more fragmented over time. Two kinds of effects could have caused this development. On the one hand, there could be country wide changes which affect firms of different industries in a different way. On the other hand, there could be industry specific changes. According to the transaction costs theory by Coase (1937) and Williamson (1979) costs of re-writing contracts for market transaction have a positive effect on integration, and the incomplete contract theory as described by Grossman and Hart (1986), mentions the problems of monitoring contracts and the difficulty to enforce them. By an improvement of institutions, those costs could decrease and fragmentation could be more likely to happen. This reason does not seem to be appropriate to explain the change in firm structure because there were not many institutional changes within the UK between 1997 – 2008.

Another nationwide effect could be the increase in competition through the enlargement of the European Union. Grossman and Helpman (2002) show that if the cost disadvantage of outsourcing through search costs and incomplete contracts are lower than the costs arising through dis-economies of scales through vertical integration, then a higher degree of competition leads to more firms engaging in fragmenting the production.[117] As explained on page 20, another effect will also appear. More competition diminishes the specialisation advantages of component suppliers, therefore will reduce the number of intermediate input suppliers. This makes it easier for that firm to break even and increases the propensity of outsourcing firms. Those effects can also point in opposite directions, where the cost effects dampens or may even outweigh the "change in the number of component supplier" effect. Grossman and Helpman (2002) also offer industry specific explanations. In general, a reduction of search costs to find a suitable specialised firm, lower fixed costs of firms which engage in outsourcing and a decrease in the production costs of specialised in comparison to vertically integrated firms could lead to an increase in fragmented firms. If the cost structure has developed differently over time then companies of different sectors will behave differently as well.

So far the foreign dimension has been neglected. It could be the case that outsourcing or FDI into other countries influence the results. If outsourcing was dominating the

[117] If the dis-economies are lower than the search and incomplete contract costs, then a higher amount of competition can lead to the exact opposite outcome. Higher competition leads to a higher propensity of having vertically integrated firms.

international interaction of firms, then the results above would not change at all. The appearance of FDI would lead to an overestimation of organisational fragmentation. On the other hand, inward FDI of companies, which already have an affiliate in the UK, will increase the number of vertically integrated firms even though, they might have been integrated before.

4.5.2. Geographical fragmentation

The analysis for geographical fragmentation will be conducted in the same manner like above. Transition tables will only be presented in the appendix on pages 278*ff*, because of the small number of firms with a changing location structure. We will focus again on the decomposition measure. We can only measure the geographical dispersion of vertically integrated firms, therefore we consider only vertically integrated firms for this analysis. We measure how geographically dispersed the internal production process of a firm is.

The change in the average distance will be decomposed again to see if the increase in distance has been caused by continuing, entering or exiting firms. Exiting and entering firms are now interpreted in a different way than before. For the calculation of the spatial measure the distance between the headquarters and the vertically integrated local units are important. Therefore if a firm becomes vertically integrated it will appear in the sample and is therefore an entering firm, even though it existed before. An exiting firm is not necessarily a firm becoming inactive, but a firm which does not own any vertically integrated plants anymore. The results are presented in table 4.4. In the last column the absolute change in distance in meters is presented.

Similar to the organisational fragmentation newly vertically integrated firms are causing the increase in the dispersion. In manufacturing it is around 79 percent, followed by 17 percent from continuing firms, where the main effect of continuing firms is the within effect. This means that vertically integrated firms got more dispersed. Exiting firms are

	Continuous					
	Within	**Between**	**Cross**	**New**	**Exit**	*Total*
Man	8.0	2.7	6.5	79.4	3.3	9,760
Ser	3.7	−1.8	1.7	100.5	−4.0	17,685

Notes:
This table is based on equation 4.9. The last column (Total) shows the absolute change in the spatial distribution (in meters) of vertically integrated firms. In all other columns (Within to Exit) values are in expressed in percentage. The first three columns (Continuing) show how much of the absolute change has been caused be continuing firms. The fourth column (New) indicates the influence of firms which entered after 1997 and the fifth column (Exit) the influence of firms which exited before 2008. We swapped the sign of the Exit column to be consistent with equation 4.9.

Table 4.4: Decomposition of the change in spatial fragmentation of local units

responsible for only 3 percent of the change, meaning that more concentrated firms have left the market. In the tradable service sector the change of dispersion is only caused by new firms.

To sum it up, the higher rate of dispersion of the average firm is mainly caused by firms becoming vertically integrated, regardless of the industry.

Implications of results

As for organisational fragmentation, the determinants of spatial fragmentation will be more closely discussed in the next chapter. We find that the share of multi-location firms and the average dispersion increased for vertically integrated firms. The change is driven by new firms and partly by continuous firms which got more dispersed. Newly vertically integrated firms set up their plants further away than the average vertically integrated firm in 1997 continuing firms set up new vertically integrated local units further away or shut down old vertically integrated local units closely located to the reporting unit. This supports our explanation from the static analysis that outsourcing became relatively cheaper than vertical investments. For example, search costs for firms to find an outside supplier decreased, or service linkages became cheaper. Therefore for a firm to disperse the internal production chain over different regions only pays off, if factor price differences are large enough. Another argument could be an increase in the importance of market coverage. The dominance of 'new' entrants can maybe explained with the costs related with setting up a new vertically integrated local unit. Setting up a new plant is expensive, therefore for firms which are already vertically integrated it will be less likely to move an existing plant to a new location than for firms which set up a local unit in a distant location to create a new vertical link.

4.6. Comparison to Other Studies

If the organisational fragmentation results are compared to other empirical studies for the manufacturing sector, the size of the degree of vertical integration seems to be reasonable. Studies by Maddigan (1981) or Davies and Morris (1995) offer mean values of a higher degree than in this chapter. The reason for that is that only big firms are considered in their analysis. The comparison of the results of Acemoğlu et al. (2010) is a little bit more difficult because they are using an even less aggregated measure than the local unit level. The results are extremely low, which is comparable to my findings. All the results are presented in table 4.5.

4.7. Summary and Conclusion

The main purpose of this chapter was to measure how fragmented UK firms are. This question was answered with the Business Structure Database which contains a sample with a couple of million observations for the period 1997 – 2008. Two dimensions of fragmentation, geographical and organisational, for two different sectors, the manufacturing and the tradable service sector, were considered. Organisational fragmentation, which can be divided into forward and backward vertical fragmentation, gave information about how many intermediate inputs are sourced from the market. The degree of

Organisational Fragmentation						
Author	*Count.*	*No of obs*	*Period*	*Info*	*Results*	*Value*
Maddigan (1981)	US	96	1947	Firm, VI direct	Degree of vertical integration of firms is significantly increasing over time	0.1047
		96	1958			0.1369
		96	1963			0.1751
		96	1967			0.1935
		96	1972			0.2257
Davies and Morris (1995)	UK	306	1985	Firm, only for vertically integrated firms	Riegler gets a degree of 0.052 for vi firms in 1997	0.0138
Acemoğlu et al. (2010)	UK	2,973,008	1996–2001	Local unit industry pair of a company	Degree of vertical integration of an industry pair of a company is very low, but a high deviation can be observed.	0.0080
Riegler	UK	158,113	1997	Firms	Degree of vertical integration is low and decreasing	0.0016
		160,244	1998			0.0014
		155,547	1999			0.0013
		146,030	2000			0.0013
		143,943	2001			0.0012
		140,688	2002			0.0012
		136,098	2003			0.0012
		132,191	2004			0.0012
		128,315	2005			0.0012
		125,012	2006			0.0010
		123,963	2007			0.0009
		122,879	2008			0.0009

Table 4.5: Comparison of empirical results

organisational fragmentation was derived with input-output tables. Spatial fragmentation indicates how far away vertically integrated local units are from their headquarters. This illustrated how geographically dispersed a production process of a company was.

To answer the research question we focused on a static and a dynamic analysis. The former showed the trends in fragmentation and the latter which firms caused the observed change. The analysis of the organisational dimension revealed that the degree of vertical integration for the average local unit or firm was extremely low, even if only vertically integrated firms were considered. This meant that the observation units are highly fragmented.

In the manufacturing sector the picture was quite clear. The degree of vertical integration decreased over time. Firms became more fragmented, regardless whether all or only multi-plant firms were considered. The decomposition of the degree of vertical integration revealed that the main part of the change in the degree of vertical integration was caused by new firms.

In the tradable service sector the results were rather similar but at a significantly lower level. The degree of vertical integration decreased if all firms and remained rather constant if only multi-plant firms were considered. The share of vertically integrated firms was lower in the service sector than in manufacturing, but when a service firm was vertically integrated, it was at a higher degree. Again, the change in the degree of fragmentation was caused mainly by new firms. The higher degree of fragmentation fits into the picture of shrinking UK firms.

We could only measure the spatial dispersion of vertically integrated local units, therefore the analysis of spatial fragmentation considered only vertically integrated local units. The average dispersion of vertically integrated local units increased for manufacturing and the tradable service sector. This dispersion was mainly caused by newly vertically integrated firms. Furthermore, also continuing firms got more dispersed. We concluded that outsourcing became more attractive for firms in comparison to setting up a plant at a different location. Only if factor-price differences are large enough, then it is still worth to keep or set up a new plant in a different location.

In summary, we find evidence that UK firms became significantly *more fragmented* between the period 1997 – 2008.

Important Note

In the first chapters we used the sample period from 1997 – 2008. The whole analysis has been conducted at the Virtual Microdata Laboratory (VML) of the Office for National Statistics (ONS) in London and Newport. To increase efficiency the ONS introduced the Secure Data Service (SDS). Researchers are now allowed to access confidential ONS data from the researcher's office computers. However, the BSD observations for 1997 have not been available until recently. Therefore in this and the following chapters we had to reduce the observation period to 1998 – 2008. To keep confidentiality of firms, the ONS encrypted postcodes. The characteristics of the original postcodes remain. We still can allocate the encrypted postcodes to local authority and measure the distance between headquarters and local units. Originally, we cleaned some postcodes manually. We do not know which cleaning procedures the ONS has used. The main results remain the same, even though some results are not significant anymore. This could be caused by dropping year 1997 or a different postcode cleaning procedure.

5. Explanations for the Organisational Structure of Firms

5.1. Introduction

In the last chapter evidence has been presented which suggested that the way an average firm is structured changed significantly over the ten years from 1998 – 2008. The number of single-plant firms has increased massively, and, if only multi-plant firms are considered, the degree of vertical integration decreased in manufacturing, and the distance between local units and their headquarters increased in manufacturing and in the tradable service sector. In table 5.1 we summarise different structures based on an organisational and spatial dimension for the manufacturing and the tradable service sector. All in all five different organisational forms can be identified, where single-plant firms are not shown in the table.[118]

Spatial dimension			**Organisational dimension**			
			Market		Vertical Int.	
	conc.	Manufacturing			20,077	(1.4%)
	conc.	Tradable Ser.			7,506	(0.2%)
			33,564	(2.3%)		
			58,808	(1.3%)		
	disp.	Manufacturing			14,872	(1.0%)
	disp.	Tradable Ser.			5,866	(0.1%)

Notes:
This table is based on table 2.1 for period 1998 – 2008. The first value of each cell is the absolute number of firms in each category. Values in parenthesis are the share of each category of the total number of firms and do not add up to 100% because single-plant firms (95.3% for man. and 98.4% for trad. ser.) are not presented. No spatial distinction is possible for firms which source from the market only.

Table 5.1: Classification of fragmentation for all three sectors

Being vertically integrated is most important for the manufacturing sector (2.4 percent),

[118] According to the definition used single-plant firms are completely fragmented. See discussion on page 169 for the problems with the classification of single-plant firms.

but hardly plays any role in the tradable service sector (0.3 percent). In general, concentration is more popular for vertically integrated firms than dispersion. With only 0.1 percent of all firms, dispersed and vertically integrated local units hardly appear in the tradable service sector. We do not have sufficient information to identify where non-vertically integrated firms are sourcing their intermediate inputs. Therefore we can present only how many multi-plant firms are sourcing solely from the market.

Many theories exist explaining which factors affect the organisational structure of firms. The purpose of this chapter is to test the predictions of many common theories about the organisational structure of firms using new and more comprehensive data for the UK which allows us to examine both the organisation and geographical structure of multi-product firms. The key question we ask in this chapter is:

What common theories can explain the organisational structure of UK firms?

The reason why a firm would let an outside supplier conduct former vertically integrated production stages (organisational fragmentation) is mainly based on two factors: incomplete contracts and knowledge capital.[119] The reasons for moving production stages to other areas (spatial fragmentation) is theoretically covered by Factor Proportion Models (FPMs) and again by the Knowledge Capital Model (KCM).[120] Additionally to those theories, two papers by Acemoğlu et al. (2007) and Acemoğlu et al. (2010) will build the foundation of the analysis. Acemoğlu et al. (2007) create a model of how a certain organisational form can influence the implementation of the right technology. Acemoğlu et al. (2010) provide the calculation of an empirical vertical integration measure by using datasets of the ONS.

The empirical evidence is not always clear, which is partly caused by differing definitions of how to measure fragmentation. To test the incomplete contracts hypothesis and the KCM, R&D expenditures and capital intensities are often used to capture how knowledge

[119] A precise description of both theories can be found in chapter 2, pages 15*ff* and 17*ff*.
[120] The theoretical description is provided on page 25 and 28.

and capital intensive the production of a good is. Acemoğlu et al. (2010) find a positive relationship between R&D intensity and integration for the downstream firm, but a negative relationship for the upstream firm using UK data. Tomiura (2005) gets a different result for Japanese firms. The higher the R&D intensity the more will be outsourced, because outsourcing leaves more resources for conducting R&D. Also Díaz-Mora (2008) finds evidence that, in high skilled industries, more outsourcing will appear. Tomiura (2005) finds that physical capital is positively related to integration, but Taymaz and Kiliçaslan (2005) find the opposite sign for Turkey. Congruent empirical evidence shows that cost-saving motives are also an important determinant for outsourcing, for example, firms paying higher wages are more likely to outsource (Abraham and Taylor, 1996; Girma and Görg, 2004; Díaz-Mora, 2008; Holl, 2008). Also agglomeration of economic activities, for example in cities, has a positive influence on outsourcing (Abraham and Taylor, 1996; Taymaz and Kiliçaslan, 2005; Holl, 2008).

International studies reveal that labour-cost differences can attract FDI, which implies that firms are willing to set up affiliates and become spatially more dispersed (Bellak and Leibrecht, 2009) but not necessarily (Bénassy-Quéré et al., 2005). Agglomerations of economic activities, such as, for example, those seen in urban areas, have a positive effect on the dispersion of a firm. This is because the accumulation of services creates positive externalities for management activities, like reduced search costs for service providers, a larger pool of high skilled workers, etc. To maximise profits, a multi-unit firm will then be better off moving production stages to remote areas with lower labour costs. Galliano et al. (2007) find empirical evidence for this. All empirical results are summarised in table 5.2.

This chapter will take advantage of many different datasets of the ONS. Again, the Business Structure Database (BSD) will be the main dataset, which has the advantage of containing nearly the whole population of UK firms. The second database used is the Business Enterprise Research and Development (BERD) database which provides the

Organisational Structure (Integration)			
Variables	Authors	Result	Comments
Age	Acemoğlu et al. (2007)	+	Results are for decision power concentration
	Holl (2008)	−	
Distance to tech. Frontier	Acemoğlu et al. (2007)	−	Results are for decision power concentration
Tech. Industry Heterogeneity	Acemoğlu et al. (2007)	−	Results are for decision power concentration
R&D intensity	Acemoğlu et al. (2010)	+	Positive effect on downstream firms.
	Tomiura (2005)	−	
Capital intensity	Tomiura (2005)	+	For Japan
	Taymaz and Kiliçaslan (2005)	−	For Turkey
Skill intensity	Díaz-Mora (2008)	−	
Spatial Structure (Dispersion)			
Unit Labour Costs	Bellak and Leibrecht (2009)	+	International study
	Bénassy-Quéré et al. (2005)	−	International study
Agglomeration	Galliano et al. (2007)	+	

Table 5.2: Effects of variables on vertical integration and geographical dispersion

data for R&D expenditures. The Annual Survey of Hours and Earnings (ASHE) is the main source for industry and regional wage data. The Annual Respondents Database (ARD) will be used for the calculation of industry capital stocks. Other data is sourced from different ONS sources freely available.[121]

By taking account of different characteristics, namely if firms are multi-plant, vertically integrated and geographically concentrated or the opposite, three different estimation stages will be conducted, to find the determinants of those characteristics. Most studies focus only on the manufacturing sector, as it is clear from results in earlier chapters, the service sector now dwarfs the manufacturing sector in size. Therefore, additionally to the manufacturing sector, we are going to analyse the tradable service sector.

One drawback of the data we use is that it only covers the organisational structure of firms within the UK. That is, we have no information on how these firms are organised

[121]See `http://www.statistics.gov.uk/default.asp`, access on 03/08/11.

in their overseas affiliates, if they have them. The ONS offers a database called the Annual Inquiry into Foreign Direct Investment (AFDI) which captures outward and inward investments of UK firms. Unfortunately, it was not possible to use this information for analysis. Data exists only for the observation period up to 2005.[122] Additionally the AFDI database is classified into enterprise groups and not enterprises. In theory, enterprise groups reference numbers should be included in the BSD, but unfortunately this reference number is inconsistent over time and sometimes missing. This problem is so severe that information for years 2004 and 2005 could not been used. As a result, this study will purely focus on the organisational structure of firms within the UK. Even though the international dimension is missing, the analysis of changes in the organisational structure of firms within the UK will still provide important insight into strategic decisions of firms. Only a small proportion of firms actually set up affiliates abroad. This can theoretically be explained by models based on heterogeneous firms. For example, according to Antràs and Helpman (2004) only the most productive firms will be able to set up foreign affiliates. Many theories about international fragmentation are based on factors which do not necessarily need an international dimension. For example, a firm employing a high amount of knowledge capital will be expected to be integrated, regardless if the company is domestic or international. Of course some variables, for example variables of the gravity model[123], should matter less, but with these caveats, the analysis of domestic fragmentation will help to find new insight in what influences the organisational structure of firms.

Finally, the analysis can only be conducted at the enterprise and not at the enterprise group level. Because of the inconsistency of the enterprise group reference numbers over time, a panel data analysis over the period 1998 – 2008 is impossible.[124] The effect on the results can be ambiguous. Large enterprise groups may produce a large variety

[122] The merger was tried at the beginning of 2010.

[123] See section 2.1.3 on page 33.

[124] See page 69 for the definitions of different units.

of products which have, according to the input-output table, a vertical connection, but goods are actually not intermediate inputs for other enterprises. On the other hand, it could be the case that some vertical linkages are ignored even though another company of the same group is providing intermediate inputs.

The analysis is conducted in three parts. In the first part a descriptive explanation about the decision of being a multi-plant or single-plant firm will be presented. This decision is important, because according to our definition only multi-plant firms can be vertically integrated. In the second stage we will consider the decision of a firm to be organisationally integrated or fragmented. The measure calculated in the last chapter will be used.[125] In the last stage the decision of a firm to be spatially concentrated or dispersed will be analysed.

The main value added to the literature is that, in contrast to many other studies, the analysis is spread over the manufacturing and the tradable service sector. As far as the author knows no one before has conducted such a precise analysis about the organisational structure of UK firms. Normally only a small number of firms are changing their organisational structure, but the large sample of the BSD allows us to identify a remarkable amount of firms changing their organisational structure. The detailed information allows us further to identify vertical local units which is important for testing theories about the spatial dispersion of firms. Detailed measures of R&D should reveal the importance of R&D intensities of firms on their organisational structure.

This chapter analyses why some firms are more likely to be fragmented than others by looking at firm, industry and regional characteristics. The main results are that firm heterogeneity has a significant impact. For organisational fragmentation we find robust and similar coefficients for the technology variables in both sectors. The more technological heterogeneous an industry is, the more likely it will be for fragmented

[125] See pages 114*ff*.

firms to appear. The closer a firm is to the technological leader, the more likely it will be vertically integrated. The results for R&D intensities are only significant in manufacturing, but a different sign appears depending on what kind of R&D has been conducted. Agglomeration has a significant negative impact on integration in the tradable service sector only. With regards to spatial fragmentation, we do not find evidence that regional wages have a positive effect on geographical fragmentation. Instead we find that firms which are large, close to the technological frontier and in a concentrated market are more likely to be dispersed. For firms of the tradable service sector agglomeration has a positive impact on dispersion.

The results give some important insights into the differences and similarities of manufacturing and the service sector. The theoretical fragmentation literature often focuses on a manufacturing firm, which conducts two kinds of activities, headquarters services and production of intermediate and final goods. In fact, the majority of firms are service firms, where the production stage is missing. This chapter suggests that there is a "core" part of firms which is similar independent of the sector. This part is affected by certain factors in the same way. For example relative technology differences between firms have the same effect in every sector. In contrast, other theories, like the knowledge capital theory, seem to have an impact only in manufacturing. Because of the increasing importance of services it is required to create new theories which take more into account the structure and characteristics of service firms.

In the next section 5.2 a short overview of the theoretical foundation will be given. After that, the datasets used will be described and linked to the testable hypothesis in section 5.3. Section 5.4 describes the sample and the empirical strategy employed for this chapter. All results are gathered in section 5.5. This chapter will be ended with a brief summary and conclusions.

5.2. Theoretical Foundation

In the typical neoclassical model a company always tries to maximise its profits. Choosing the right organisational structure should help to achieve this target. For example, to benefit from regional factor price differences, a company can decrease its production costs. Factor prices can therefore affect the spatial structure of the firm. If factor price equalisation cannot be achieved between regions, it could be worthwhile for a company to set up a plant in a region with different relative factor prices, for example if land is expensive like in London it can pay off to establish a new plant in the East Midlands (Helpman, 1984; Helpman and Krugman, 1985; Venables, 1999; Jones and Kierzkowski, 2001; Markusen, 2002; Van Long et al., 2005). There is evidence that factor price differences are still prevailing in the UK (Bernard et al., 2002, 2008), so even within a country we would expect those models to work. FPMs are discussed on pages 25*ff*.

One main determinant of organisational structure is the headquarters service[126] intensity of an industry. If a firm is part of a headquarters service intensive industry, it is more likely for the firm to have an integrated structure. Two popular theories can explain this. The KCM by Markusen (2002) assumes that to reveal knowledge capital like technological know-how to an outside manager could lead to moral hazard of that agent. For example, the manager could, after the knowledge was transferred, use it for its own purposes and turn into a competitor. Therefore knowledge intensive industries will tend to be vertically integrated. The KCM is described on pages 15*ff*.

Antràs and Helpman (2004) show how incomplete contracts affect firms of different headquarters service intensive sectors. In general, incomplete contracts lead to an ex-ante underinvestment problem of an intermediate input supplier I and a final good producer F. F can own I or could leave it independent to an unrelated manager. Ownership is crucial so the underinvestment is mitigated. According to the theory of property rights

[126]It is very broadly defined and consists of R&D, marketing, advertisement, and is normally high skilled labour and capital intensive.

by Grossman and Hart (1986) the best outcome is achieved if the company owns the production stage, whose ex-ante investment is more important in the production process. Based on this result, Antràs and Helpman (2004) show that a firm in a headquarters service intensive sector is more likely to be integrated and firms in more labour and component intensive sectors will tend to outsource. Please refer to pages 17*ff* for further information.

Acemoğlu et al. (2010) establish a model to explain specifically the property rights approach of incomplete contracts and how the technological level of the final good producer or the intermediate input supplier affect the organisational structure. They consider three organisational forms: non-integration, backward vertical integration or forward vertical integration. Their main result is that the more technology intensive a firm is, the more likely it is to be vertically integrated, because ex-ante investments are becoming more important. So if the downstream firm is R&D intensive, it has a higher incentive to be vertically integrated, but if the supplier is the more advanced firm, the probability of backward vertical integration will decrease. A more comprehensive explanation can be found on pages 21*ff*.

Another paper by Acemoğlu et al. (2007) focuses on how technological differences between firms and their distances to the technological frontier affect the decentralisation decisions of firms. A manager has the advantage of knowing better how to implement a new technology, but managers often have an incentive to follow different motives than a principal. This creates a trade-off. A principal can observe other firms or can learn from her own experience. Therefore if a firm is in a market where already many other firms have implemented a new technology (in other words, when a sector is homogeneous) a principal does not need any manager to choose the right decision. Therefore the decision power will be concentrated. If a firm is relatively more advanced than any other firm, for example if it is the firm at the technological frontier, then the principal faces problems again to choose the right way of implementing a new technology. Therefore delegation will be the preferred choice. A more detailed summary of that model can be found on pages 23*ff*. This model is based on firm internal decisions. Instead of thinking of internal decisions I will treat the model in the same way as Acemoğlu et al. (2010) between the option of having a production stage being conducted internally or externally. If the industry is very homogeneous it will be easier for a firm to use the most efficient technology and therefore a higher degree of vertical integration is expected. In a very heterogeneous environment it can be better to let a specialised supplier carry out parts of the production process because of better information on the latest technology. With regards to the distance to the technological frontier, the further away a firm is from the industry leader, the likelihood of integration should increase. Following the argument of the internal decision process, a firm producing at the technological frontier should be fragmented and a firm distant to the frontier should be integrated. The argument is that a technological leader requires a specialised input producer to be able to further increase productivity and firms far away from the frontier can just copy the production process of different stages of the production chain from other firms. Those implications are not as convincing as for the internal decision process. The reason is that, for the decision of integration or fragmentation, a technological leader may not be able to find outside suppliers which are able to produce the required intermediate inputs, or a technological leader does not want to reveal the technology used. This would lead to an opposite result that technological leaders will be more likely vertically integrated.

All these theories mentioned require detailed data at the plant, firm or at least at a quite disaggregated industry level which is often difficult to find. For example, to calculate technological differences firm level data is required. The degree of spatial dispersion needs information on the location of local units. Fortunately the ONS offers plenty of sources for the required information. The main difficulty is to tidy up the data and connect it with each other. In the next section the databases used for testing the theories will be introduced. The main explanations for the cleaning of the data can be found in the appendix on pages 283*ff*.

5.3. Data Description

The majority of the databases comes from the VML of the ONS which offers a large variety of different firm and individual level information of many different areas.

BSD: The observation period is from 1998 – 2008. A comprehensive data cleaning has been conducted, which is precisely explained in chapter 3. Acemoğlu et al. (2010) use the ARD, which consists of more variables but the sample size is significantly lower. The reason why the sample size matters is that even for large firms a change in the organisational structure is an unusual event. Therefore a huge sample is required to have enough variation to calculate accurate coefficients. Data about employment, turnover, age and location are available at the firm level. This data is needed for the creation of the dependent variables. This dataset enables us to identify vertically linked local units, which is crucial for testing the hypothesis about spatial dispersion.

ARD: With the ARD the calculation of the average real capital stock and capital intensities of a firm in a 4 digit Standard Industrial Classification (SIC) industry is possible. Capital intensities are calculated by real capital stock divided by employment. Some basic descriptions about the ARD are provided on pages 95. Martin (2002) and Gilhooly (2009) explain in more detail how to create the capital stock. A summary of the procedure can be found in the appendix in section C.2. Only firms have been employed for which less than 50 percent of annual observations have been imputed. Capital stock data can only be used from 1998 – 2006. This would lead to a loss of the years 2007 and 2008. Therefore we will use capital stocks only as a robustness check. We hope to cover capital intensity with R&D intensity, which are available for every year.

BERD: To measure knowledge intensity a database called BERD will be used. This database is based on an annual questionnaire which is sent to all firms the ONS believes are engaged in R&D. The information on which firms to approach is gleaned from various sources, but most respondents are those from the last BERD survey. The data is available for the whole observation period. According to Griffith and Hawkins (2003)[127] 85 percent of R&D flows from the last year are captured by surveys and the rest is generated through a stratified sample. The BERD includes data on the R&D expenditure on in-house R&D and R&D which was bought from an unrelated firm, the number of people employed for R&D activities, a SIC code, reporting and enterprise reference numbers. A link between the BERD R&D expenditures and industries in the BSD can be created. Several problems arise to merge the BERD with the BSD. The procedure chosen to circumvent those problems can be found in the appendix in section C.1.1.[128]

ASHE: The ASHE is intended to be a one percent sample of all UK employees and offers detailed information about them. The observation period is 1998 – 2008 and every year contains more than 200,000 observations. Besides information on wages and hours worked, the ASHE contains information on where the employees are living and how skill intensive their job is.[129] To measure regional factor price differences, the average weekly basic wage[130] in a local authority was calculated. To measure the wage level in an industry the average weekly basic wages for the 4 digit SIC level was calculated. The cleaning procedure is explained precisely in appendix C.1.2 on page 288.[131]

Regional Data: Different countries have different characteristics, which are often used to explain international fragmentation. Also different regions within the same country are different. To capture those differences regional data was gathered. The variable for

[127] This publication seems to be only available at the VML.

[128] For example, observations in the BERD are reporting units, and many enterprise reference numbers are missing. By using postcode and industry classifications, these problems were mitigated.

[129] The average wage for skilled and unskilled workers can have different effects on the fragmentation decision of a firm. Unfortunately, the skill classification is inconsistent over time. Therefore we can use a skill intensity measure only for robustness checks. See appendix page 288 for more explanations on the skill intensity measure.

[130] Weekly gross wages would be more appropriate. This variable is unfortunately inconsistent over time.

[131] The ASHE does not contain data for Northern Ireland and British tax havens like the Scilly Isles etc. Table C.4 on page 289 shows and describes which industries could not be merged with the industries included in the BSD.

the identification of the location of a firm is an eight digit postcode, which can be aggregated up to postcode areas or postcode sectors. Because the postcode data depends solely on the efficiency strategies of the Royal Mail, no statistical data exists for postcode areas, districts, etc. For local authorities far more data is available. Local governments influence the policy in their local regions, therefore allocating firms to its local authority is more appropriate than to postcode areas. The National Statistics Postcode Directory (NSPD) 2009[132] was used to link every postcode to a local authority code. A look-up table from the NSPD from 2008 helped to identify the local authority code. With the name of the local unitary authority a broad range of data from different ONS publications like "Region in Figures" and "Regional Trends" can be used. The very disaggregated district level was further aggregated to the county level and the regional level.

5.4. The Sample and Empirical Strategy

A similar sample to that of chapter 4, without year 1997, will be used. Generally, we have UK data for the observation period 1998 – 2008, with 1.5m observations in the manufacturing and 1.4m in the tradable service sector.[133] Note that, because of the large size of the tradable service sector, `Stata` reached its memory limits. Therefore we had to select a 30 percent random sample of tradable service firms which leads to 1.4m observations.[134] Selected samples are presented in the *Full-All* columns of table 5.3. The multi-plant sample is significantly smaller than the sample including all firms. In the BERD sample only firms of the BERD which could be merged with the BSD sample are kept. Therefore the sample is even smaller than the multi-plant sample.

Fragmentation has two dimensions, a spatial and an organisational dimension.[135] These

[132] It was 2007 on the SDS server.

[133] Both sectors are significantly different, therefore the split into two sub-samples shall help to compare the determinants of the organisational structure of firms between those sectors. See page 88 for a more detailed explanation about defining the two sub-samples.

[134] See footnote 162 on page 179 for a description of the random sample selection.

[135] See section 2.1.1 for a more detailed description.

	Manufacturing			Tradable Services		
Sample	Full		R&D	Full		R&D
Sub-sample	All	MP	All	All	MP	All
1998	153,680	11,397	1,820	99,047	11,455	624
1999	149,454	11,179	1,880	105,833	11,731	772
2000	141,043	10,941	2,209	110,380	11,884	953
2001	138,158	10,559	2,283	113,891	11,733	1,095
2002	134,945	10,159	2,792	115,464	11,304	1,437
2003	130,834	9,539	3,026	117,165	10,814	1,998
2004	127,113	9,022	3,347	125,751	10,205	2,689
2005	123,168	8,465	3,577	134,446	9,342	2,966
2006	119,771	8,125	4,243	143,843	8,970	3,746
2007	118,830	7,755	4,583	153,199	8,623	4,639
2008	117,697	7,365	4,064	161,455	8,251	4,394
Total	1,454,693	104,506	33,824	1,380,474	114,312	25,313

Notes:
This table presents the number of firms for three different samples: All firms, multi-plant firms (MP) and firms which only appear in the BERD sample. The BERD sample is significantly smaller because it keeps only firms from the BERD which can be merged with firms of the BSD.

Table 5.3: Sample size for different sub-samples

two dimensions identify four different organisational structures which are presented in table 5.1. These organisational structures range from completely vertically integrated and concentrated to completely organisationally fragmented and spatially dispersed. A special case are single-plant firms, which will be dealt with separately, because they could be completely fragmented or completely integrated.[136] This leads to the following five organisational structures:

1. Single-plant firms,
2. multi-plant firms which are not vertically integrated and spatially concentrated,
3. multi-plant firms which are not vertically integrated and spatially separated,
4. multi-plant firms which are vertically integrated and spatially concentrated,
5. multi-plant firms which are vertically integrated and spatially separated.

[136]See page 169 for a further discussion.

As table 5.1[137] illustrates, the number of firms of a specific category differs between manufacturing and the tradable service sector. It is expected that different theories affect the organisational structure differently. For example, the Factor Proportion Model and the proximity-concentration trade-off should be suitable to explain the spatial dimension. If the decision is about sourcing the intermediate inputs from the market or from an affiliate then it will depend on incomplete contracts, knowledge capital and technological factors.

5.4.1. Empirical strategy

One possible way to estimate the determinants of structures 1 – 5 would be to use a polychotomous dependent variable model with five different, unordered states. However, common estimation methods require strong assumptions (Maddala, 1983), which do not hold in this case. The Independence of Irrelevant Alternatives (IIA) makes the Multinomial Logit Model not feasible. IIA states that, for example, the probability of a firm choosing a type 1 (single-plant firm) or type 2 (multi-plant, not vertically integrated and geographically concentrated) structure should not be influenced by other organisational choices. If we add type 3 structures to the possible organisational forms, some type 2 firms will consider this alternative. This will influence the probability of a firm choosing a type 1 in comparison to a type 2 structure.[138] A Multinomial Probit Model relaxes the IIA, but because of its computational intensity applied research with more than three states is not recommended.[139] A computational feasible method is a Nested Logit Model, but the structure would be rather arbitrary and furthermore no correlation

[137] In this graph the government office region was used as a measure of concentration. If a firm has only local units within the same government office region, we regard to it as concentrated firm. In the empirical analysis below I will use instead of the government office region the local authority level which are significantly smaller. Therefore I expect the numbers in table 5.1 to undervalue the dispersed and overvalue the concentrated firms.

[138] The probability of choosing type 2 will go down, and if the probability of choosing type 1 remains the same, the probability of choosing type 1 relative to type 2 will go up.

[139] See Maddala (1983); McFadden (1984); Greene (1997).

of the disturbance terms of states in different nests should arise.

Our empirical strategy will therefore follow a different approach and focuses on the two basic dimensions of fragmentation, space and organisation, separately. Instead of having one estimation stage, three separate estimation stages will be conducted. This has several advantages. Fixed effects models can be used to control for fixed firm specific factors which are unobserved but which may be correlated with the determinants of interest. Additionally to dependent binomial variables indicating if a firm is fragmented, continuous measures can be used. The degree of vertical integration calculated in the last chapter[140] also takes account of changes in the degree of vertical integration within vertically integrated firms. A dichotomous variable does not differentiate between firms which are vertically integrated to 100 percent and firms which are to just 0.1 percent. We also derived a continuous spatial measure. The basic estimating equation takes the following form:

$$\begin{aligned} Org.\ Structure &= (technology\ vars,\ Knowledge\ Capital,\ factor\ price\ diff.) + \\ &+ (firm,\ industry\ and\ regional\ controls) + dummies + \varepsilon \end{aligned} \tag{5.1}$$

The dependent variable, the organisational structure, and the inclusion and the effect of the explanatory variables are different in every estimation stage. The variables within the first brackets are the variables of interest. How do technology variables, factor price differences and knowledge capital influence organisational structure? Many other controls will be employed, which consists of firm, industry and regional characteristics. Additionally, we will use firm and time dummies.[141] Before the explanatory variables are allocated to the different stages, those variables will be discussed.

[140] See section 4.4.1 on page 114.

[141] For standard OLS regressions we will use regional and industry dummies instead of firm fixed effects.

5.4.2. Explanatory variables

Technology variables

Homogeneity/heterogeneity measure: According to Acemoğlu et al. (2007) a measure of technological heterogeneity or homogeneity influences the choice of a company to concentrate or to decentralise its decision making power. We use this theory for the decision to let an outside producer or a firm-internal plant produce the intermediate input. An increase (decrease) in heterogeneity (homogeneity) will lead to an increase in the degree of fragmentation within a firm. The more (less) homogeneous (heterogeneous) firms of an industry are, information about the production technology can be gained easily from other firms and using a new technology can be easily implemented within the firm. Acemoğlu et al. (2007) use an industry measure for heterogeneity which is represented by the dispersion of the firm productivity growth rate within an industry. The dispersion is captured by the difference between the 90^{th} and the 10^{th} percentile in the productivity growth distribution. If growth rates differ a lot, then the heterogeneity measure will have a large value. If they are identical, then the value will be zero.

$$Heterogeneity_{jt} = (\Delta \ln y_{jt})^{90} - (\Delta \ln y_{jt})^{10} \tag{5.2}$$

where j stands for the industry, i for the firm, and t for the time period.

Acemoğlu et al. (2007) use value added per hour as a productivity measure, which is not available in the BSD. I use labour productivity, calculated as turnover per employee, instead. In contrast to Acemoğlu et al. (2007), many small firms are included in the BSD which could be problematic because growth rates of small firms are rather fluctuating. Given a constant number of employees, a change in sales can lead to significant changes in the productivity rate per worker of that firm which might create a picture of a heterogeneous sector even though the changes in the productivity growth rates are caused by small, economically insignificant firms. Like Acemoğlu et al. (2007) I will use only firms with more than 20 employees. Of course, the majority of companies are rather small, and using only firms with more than 20 employees bears the risk of underestimating the technological heterogeneity of an industry. Therefore we employ another measure where a three year average growth rate for robustness checks.

Distance to frontier: The distance to the technological frontier is another important determinant in the model of Acemoğlu et al. (2007). As stated on page 153, contrary to them we expect firms at the technological frontier to be more likely to be vertically integrated because suppliers may not be able to supply the required intermediate inputs. For firms far away from the frontier it will be easier to find supplier for their products. The only measure of productivity available in the BSD is turnover per worker. Acemoğlu et al. (2007) calculate the distance as the difference of the firm's productivity to the productivity of the 99^{th} percentile of the firms in the same four digit sector:

$$Distance\ to\ Frontier_{ijt} = \log(y_{ijt}) - \log(y_{Fjt}) \tag{5.3}$$

where F represents the frontier productivity.

Age: Acemoğlu et al. (2007) modify their model and by assuming that firms can learn how to implement a new technology by their own experience instead of depending on other firms. A young company does not have any experience, therefore relying on a manager is more profitable. Old firms, which have had enough successful implementations of technologies, are better off by concentration. Holl (2008) expects the opposite effect. The older the firms are the more likely they are to subcontract non-core activities to outside suppliers. This is because they can focus more on their own core-activities and have also more time to find suitable contractors. The BSD includes the date of birth for all companies, where the date is censored in 1973.

Factor price differences

In theory, the main drivers of geographical fragmentation are factor price differences. For example, labour intensive production stages should be moved to the regions where labour is relatively abundant. We will control in our model for factor price differences by using regional wages. The higher the wages within an area, where the headquarters are located, are, the higher should be the probability of sourcing inputs from other places. The wage data comes again from the ASHE, and the average wage was calculated at the local unitary authority level. There are several limitations of capturing factor-price difference with regional wages: There have been little relative changes in industry wages across this short time period. Another limitation could be that higher regional wages could be partly explained with higher regional labour productivity. Therefore the results of factor-price differences could be downward biased.

Hold-up hypothesis and knowledge capital

The hold-up hypothesis suggests that if a sector is headquarters service intensive, then integration will be the profit maximising strategy, if it is a component-intensive sector, then outsourcing is more likely.[142] The KCM states that not all intermediate inputs are sourced from the market because there are ownership advantages of a firm, which are better used by being internalised then externalised to other firms. The more prevailing ownership advantages are for a company the more likely it will be integrated. The hold-up hypothesis and the knowledge capital theory show in the same direction, so a higher degree of headquarters service intensity makes integration more likely. To measure knowledge intensity we use R&D intensities, which is quite common in the empirical literature (for example Acemoğlu et al., 2010). Tomiura (2005) uses a physical capital to

[142]Because of incomplete contracts hold-up problems arise (Grossman and Hart, 1986). The hold-up problem leads to a potential underinvestment for a component supplier. This underinvestment can be mitigated by offering a higher share of the profits to the intermediate input supplying plant. Outsourcing increases the profit share for a subcontracting plant. The organisational structure depends now on the characteristics of the industry.

labour and a human capital to labour ratio. One way of capturing headquarters service intensity is by using the R&D information from the BERD. A labour measure and a R&D expenditure intensity measure will be created. For the calculation of the labour measure we use the BERD information on "scientific" staff, consisting of scientists and engineers, technicians and other supporting staff like secretarial or clerical staff. The reason why a scientist is treated equally to a secretary is, that those types of workers are complements. Without supporting staff the scientist would be less productive. We then add up all the scientific staff of an industry and divide it by total industry employment. The superscripts indicate the data source.[143]

$$scientific\ employment\ ratio_j = \frac{research\ staff_j^{BERD}}{total\ employment_j^{BSD}} \tag{5.4}$$

Second, a similar method is applied for the expenditure measures. The BERD offers an in-house R&D and a market sourced R&D variable. In-house R&D can also be conducted for other firms. Therefore adding up external and internal R&D would include double counting. Instead both measures will be included as explanatory variables in the regressions.

$$in\text{-}house\ R\&D\ ratio_j = \frac{in\text{-}house\ R\&D\ expenditure_j^{BERD}}{total\ turnover_j^{BSD}} \tag{5.5}$$

$$external\ R\&D\ ratio_j = \frac{external\ R\&D\ expenditure_j^{BERD}}{total\ turnover_j^{BSD}} \tag{5.6}$$

Even though this proxy of R&D intensity is quite popular it might not capture knowledge capital perfectly because it is a flow and not a stock measure and therefore does not take account of past investments. Acemoğlu et al. (2010) use also the BERD and highlight that the distribution of R&D across industry is rather skewed. Additionally, it can be the case that the R&D figures are better reported for industries with many large

[143]In appendix C.1.1 on pages 283*ff* we describe precisely how we cleaned the BERD.

firms, which are also more likely to be vertically integrated. This could create a spurious correlation and bias the results. Therefore Acemoğlu et al. (2010), page 30, suggest to use physical capital intensity as an additional measure. This measure is less skewed and more accurately reported. The problem is that capital intensity might not be as accurate to capture knowledge capital, and as mentioned before, capital stock data is only available until 2006. A measure of the capital intensity of an industry can be calculated by using the ARD. A perpetual inventory model was employed and a real firm capital stock was created[144], summed up by industry and then divided by number of employees of that industry:

$$Capital\ Intensity_{jt} = \frac{\sum_{i=1}^{n} real\ Capital\ Stock_{ijt}^{ARD}}{\sum_{i=1}^{n} Employment_{ijt}^{ARD}} \tag{5.7}$$

Control variables

Firm size effects: Firm size is used in empirical studies to take account of many different aspects. Tomiura (2005), for example, argues that the bigger the company the larger is the market power and therefore the easier it is to find contracting partners. Abraham and Taylor (1996) focus on the "specialised service" argument. Small firms do not have the possibility to produce all intermediate inputs required above the minimum efficiency scale, therefore, to be competitive, they have to outsource those production stages to specialised firms. The second argument is more in favour of the definition we are using for identifying vertically integrated firms. Only larger firms, which can produce intermediate inputs on their own in a sufficient amount, can be vertically integrated. Therefore I expect that the larger the firm is the higher is the probability of being vertically integrated. Employment as a firm size measure will be used. A non-linear relationship between the size of a firm and its organisational structure is expected. The bigger a company gets, the more likely it will be that the minimum efficiency scale can

[144] See section C.2 in the appendix for detailed explanations how the capital stock measure has been calculated.

be reached.

Foreign ownership: It is evident that affiliates of multinational enterprises are on average larger and more productive than domestic firms.[145] But higher productivity and larger size might not be the only reason for foreign firms having another organisational structure. Dunning and Lundan (2008) mention that the hierarchies of multinationals can differ from that of domestic firms "*because of differences in cross-border cultures, political and economic systems, language and ideologies, and institutional structures.*"[146] Girma and Görg (2004) add that foreign firms are often part of a vertical production chain, therefore they will be specialised and by definition more inputs have to be sourced from other plants of the same firm. Díaz-Mora (2008) uses the same argument but comes to the conclusion that because of the focus on only one specific task fewer subcontractors are needed. Girma and Görg (2004) and Díaz-Mora (2008) agree that the international network of MNEs makes it easier to find external and more efficient providers of intermediate inputs. The BSD data contains an indicator for foreign ownership.[147] No information is contained about foreign affiliates of foreign owned firms. To follow the argument of Girma and Görg (2004), if there are other affiliates in the UK then they should be more likely to be vertically integrated than domestic firms. If the company gets its input from affiliates abroad they will not be recognised, so a company might be regarded as a fragmented firm, even though it is vertically integrated. The culture from the home country can affect the organisational structure of a company in any direction, therefore a foreign ownership dummy can have a positive or negative effect on the probability of a firm of becoming vertically integrated.

[145] See Navaretti and Venables, 2004 for an overview of empirical studies

[146] See Dunning and Lundan (2008), page 235.

[147] This country code enables to identify the location of the foreign owner, unfortunately this country code is inconsistent over time.

Competition: Grossman and Helpman (2002) mention that an increase in competition can lead to an increase in fragmented or integrated firms, depending on different market characteristics like costs through incomplete contracts and costs of dis-economies through vertical integration. Available measures for market concentration are the C4 index which is a concentration index capturing the market share of the four biggest firms in an industry (for example used by Pugel, 1981), the Lerner index, which is used by Acemoğlu et al. (2007) and the Herfindahl index. The data available in the BSD allows us to use the C4 measure and the Herfindahl index. The Herfindahl index is calculated as $Herfindahl_j = \sum_{i=1}^{N} s_{ij}^2$, where s_i represents the market share of company i in industry j. The concentration index shows the market share of the biggest companies, for example $C4_j = s_{1j} + s_{2j} + s_{3j} + s_{4j}$, where the s_{ij} represents the market share of the four biggest companies in a specific industry j. Total sales (turnover) data of all firms can be used for the calculation.

Cost efficiency measures: One important argument for fragmenting the production process is to decrease costs. It is assumed that companies which pay higher wages, after controlling for skills, in comparison to other firms have a higher incentive to outsource. Abraham and Taylor (1996) argue that firms pay above-market wages to increase the workers work spirit and also to attract higher quality workers. Firms will consider this strategy especially for core workers. High wage firms will also pay higher wages to non-core activities like janitorial services, regardless if they are highly unionised or not. This is because of workers equality preferences, that if some workers earn a high income, all workers should receive an above the average income. Their theory is supported, by empirical evidence of Blau (1977). Costs can be reduced by outsourcing those overpaid non-core activities. To capture this effect the average industry wages are calculated. We derive the average basic weekly payments in a four digit SIC industry from the ASHE database.[148] [149] Ideally, firm level wages should be used, but the required data does not exist. We can only check if industries paying higher wages will be more likely to outsource.

The degree of unionisation can affect the probability of outsourcing. On the one hand, unionised firms are characterised by higher wages, but, on the other hand, there could be special agreements which impede fragmentation of production (see Abraham and Taylor, 1996 and Girma and Görg, 2004). The Union membership status comes from the ASHE database and was calculated by taking the share of employees in a specific four digit SIC industry, which wages were set with reference to a collective agreement (see ASHE Dataset User Documentation).

Agglomeration: Agglomeration effects can influence the organisational structure decisions of a company. A company which is located within an urban area is more likely to have a fragmented production chain. The reason is that in metropolitan areas service providers are gathered, therefore it is more likely to find a subcontracting partner at lower search costs. Furthermore, the more diverse the amount of specialised services offered in a specific region are, the greater is the decreasing effect on production costs which makes it even more likely for a company to organisationally fragment its production (Van Long et al., 2005). Abraham and Taylor (1996) use a dummy variable for indicating companies which are located in centralised urban areas, for example with at least 100,000 people. Holl (2008) points out that it is not the population on its own that is important, but the density of economic activity. Therefore she uses as a measure

[148] More suitable would be using the average gross weekly payments, unfortunately this measure is not consistent over time. In the period 1998 – 2003, 2004 and the period after 2004 the gross payments consist of different income types. For example, additionally to the basic wages and premium wages in the current definition a payment type called "other pay" was added capturing wages received in the pay period for other reasons. For a detailed comparison please refer to the ASHE Dataset User Documentation.

[149] For robustness checks we add, like Girma and Görg (2004), two variables containing information on the average wage of highly skilled and unskilled workers. Unfortunately, because of an inconsistent job classification the analysis is rather limited. See section C.1.2 in the appendix on page 288 for further details.

regional industrial employment density for a specific year. The size of local unitary location is gained from various "Region in Figures" publications. The population was gained from the "Population Estimates" database of the ONS.[150]

5.4.3. The three analysis stages

We now discuss the three estimation stages and will allocate the variables to the right stage. The *first* stage is about being a multi-plant or single-plant firm. Therefore the dependent variable is a binomial discrete variable. The full sample will be used. If a single-plant firm structure was chosen, then, according to our definition mentioned in chapter 4.4.1, these firms are producing only one kind of product, are organisationally completely fragmented and spatially concentrated. Of course, it can be the case that single-plant firms exist which produce certain intermediate inputs, however if the average company size is taken into account, it seems rather unlikely that the average single-plant manufacturing company with 12 employees is able to produce its own intermediate inputs. In the service sector the picture is less clear. If a small web-page producer in London is considered, then it can be the case that all the required intermediate inputs like accounting, R&D and programming are done within the company. This company would be vertically integrated to 100 percent. A look at the data reveals that single-plant firms seem to be quite different from multi-plant firms.[151] What actually determines that firms become multi-plant firms? Very few papers have been published about multi-unit firms, where one part is focusing on determinants (Chandler, 1990; Kim, 1999; Galliano et al., 2007) and the other part on the performance of multi-plant firms (Chandler, 1990; Audia et al., 2000). Chandler (1990) points out that new technologies, economies of scale and scope can only be fully realised in a multi-unit structure. Kim (1999) highlights that

[150]The whole population was used to calculate the population intensity measure.

[151]Single-plant firms are significantly smaller than their multi-plant counterpart, had in 2008 on average 10.6 employees in manufacturing and 3.5 in the tradable service sector in comparison to an average multi-plant firm employment of 247 and 171 respectively. Turnover for the average single-plant firm was £1,200k and £310k in comparison to the average multi-plant firm of £45,100k and £12,500k.

the Multinational Enterprise (MNE) literature is actually a special case of the multi-unit literature. First location advantages must exist to have a plant abroad. Also factors like proximity to the final market and transport costs have to be considered. Only if some internalisation advantages exist, those local units abroad will be owned by the company. Therefore both organisational and spatial fragmentation factors are of importance. Kim shows that most firms in the US manufacturing sector started to integrate forward into distribution and not backward into raw materials. Therefore he argues that economies in marketing are even more important for becoming a multi-unit firm. Factors like a brand name and reputation are of better use when used within the firm than licensed to outside firms. Galliano et al. (2007) mention the search for market power as a determinant of a multi-plant structure. Audia et al. (2000) add that a multi-unit structure gives opportunities to firms to cooperate. For example, instead of competing with a firm in the same markets it is possible to agree that both firms will act in different regions to make use of their market power.

The size of a firm matters (Galliano et al., 2007). Concentration of production in one plant creates a trade-off between having economies of scale at the plant level and informational disorder. Dividing a firm into smaller, more manageable profit centres will ensure a better performance of a firm. Concluding, we expect all factors causing geographical and organisational fragmentation also to influence the decision of becoming a multi-plant firm. Size and competition is expected to matter significantly. Therefore in this stage all available explanatory variables will be included. The extremely large sample precludes estimation of the first stage on the entire population of firms in the same sector. We therefore select a random 30 percent sub-sample for the tradable service sector.[152]

In the *second* stage the question of being vertically integrated or not will be discussed. Two vertical integration measures are available. On the one hand, a discrete choice variable indicating if a firm is integrated or not and, on the other hand, a continuous

[152]This restriction was necessary because of memory limitation at the VML.

measure indicating the degree of vertical integration are available. The measures are based on Acemoğlu et al. (2007) and Abramovsky and Griffith (2007), who use input-output tables to create a link of vertically integrated local units of a company.[153] The vertical integration dummy is one for a firm if at least one vertically integrated local unit exists. The continuous measure is calculated as the average of the degree of vertical integration of the local units of a firm. In this stage it will be analysed if technology matters for vertical integration and what influence R&D and capital intensity will have on the decision of a firm to be vertically integrated. Having a firm level measure of R&D intensities would be ideal because the theoretical foundation is based on the knowledge intensity at the firm and not at the industry level. The BERD offers firm level data. The drawback of using the BERD sample is that the sample size will be dramatically reduced. To see if results are similar, regardless of using industry or firm level R&D expenditures, the analysis will be conducted with both samples.

In the *third* stage the spatial structure of firm will be analysed. The sample used will be the multi-plant sample. Two kinds of dependent variables will be employed. The discrete measure is a multi-location dummy and indicating if a company has vertically integrated local units in more than one local unitary authority. The continuous measure measures how far away are on average vertically integrated local units from their headquarters. We will employ a within-firm measure, which calculates the average distance of all vertically integrated local units within a firm.[154] The main variable of interest is factor proportion differences. The number of observations for each sample are included in table 5.3.

[153]The vertical integration measure is explained in section 4.4.1.

[154]A more detailed description can be found in section 4.4.2 on pages 127*ff*.

Variable	Level	Based on	Comments	Expected sign		
				MP	VI	ML_v
Technology Variables:						
Heterogeneity	Industry	Acemoğlu et al. (2007)		?	–	–
Dist. to tech. Frontier	Firm	Acemoğlu et al. (2007)		?	–	–
Age	Firm	Acemoğlu et al. (2007)		+	?	+
		Holl (2008)				
Factor Price Difference Variables						
Factor prices	Location	Helpman (1984)	$Wage_{lua}$	+		+
Incomplete Contracts and Knowledge Capital Variables:						
Hold-up hypothesis	Industry	Antràs and Helpman (2004)	In-house R&D Int.	?	+	+
		Tomiura (2005)	External R&D Int.	?	+	+
		Helpman (2006)	Sci. Staff Int.	?	+	+
			Real Cap. Stock	?	+	+
Knowledge Capital	Industry	Markusen (2002)	Like hold-up	?	+	+
Control Variables:						
Firm Size	Firm	Abraham and Taylor (1996)	Employment	+	+	+
		Tomiura (2005)				
Foreign Ownership	Firm	Girma and Görg (2004)		+	?	?
		Dunning and Lundan (2008)				
		Díaz-Mora (2008)				
Competition	Industry	Grossman and Helpman (2002)	Herfindahl	?	?	?
		Acemoğlu et al. (2007)	C4	?	?	?
Cost cutting measures	Industry	Abraham and Taylor (1996)	$Wage_{ind}$	?	–	–
	Industry	Girma and Görg (2004)	Coll.Agreement Int.	?	?	?
Agglomeration	Location	Abraham and Taylor (1996)		–	–	–
		Holl (2008)				

Notes:
MP … multi-plant firms, VI … vertically integrated firms and ML_v … multi-location firms
+ increase of probability of being status mentioned in header

Table 5.4: Overview of explanatory variables in the empirical literature for chapter 5

5.4.4. Estimation procedure

Ideally, estimated coefficients of a model are interpreted as causal effects. This interpretation is only possible if there are no endogeneity issues caused by firm heterogeneity (omitted variables), simultaneity and measurement errors (Wooldridge, 2002, chapter 4). The first two will be discussed in more detail.[155] All three effects lead to biased and inconsistent results. Equation 5.8 shows the estimated model.

$$O_{it}^{org,\,geo} = \beta_0 + \beta_1 X_{i,t-1} + \beta_2 X_{j,t-1} + \beta_3 X_{r,t-1} + \gamma_1 C_{i,t-1} + \gamma_2 C_{j,t-1} + \gamma_3 C_{r,t-1} + \\ + D_t + a_i + \varepsilon_{it} \tag{5.8}$$

where indices i represents the firm, j the 4 digit SIC industry, r the local unitary authority region and t time. X are the variables of interest at the firm, industry and regional level and C the control variables at the same three levels. Additionally, dummies are added. ε is the idiosyncratic error-term. Crucial for analysis is the term a_i. This term is called firm fixed effect and captures unobserved *firm heterogeneity* meaning all firm characteristics which are specific to a firm and do not change over time. If unobserved effects are not considered in the regression then the estimated coefficients can be biased. For example, the following equation could be estimated:

$$Fragmentation_{it} = \beta_0 + \beta_1 frontier_{it} + \beta_2 corporate\ culture_i + \varepsilon_{it} \tag{5.9}$$

where $frontier$ measures the proximity to the technological leader. *Corporate culture* may measure the attitude of the company towards its employees. For example, how many fringe benefits are offered, how much influence have employees on company's decisions, etc. We cannot observe the latter, but we expect that the more "employee friendly" the

[155] Wooldridge (2002) states that endogenous variables are very broadly defined in econometrics. If a variable is correlated with the error term, the variable is endogenous, if the error term and the variable are uncorrelated, then it is a exogenous variable. All those three situations lead to having endogenous variables on the right hand side of the equation.

corporate culture is, the higher will be the labour productivity (through motivation and commitment), which increases the proximity to the technological frontier. It can also be the case that a stronger influence of employees will make it less likely to outsource production stages. The corporate culture variable will be captured by the error term, which is correlated with the frontier variable. This leads to a biased estimation of β_1. An "employee friendly" corporate culture will have a negative impact on $fragmenting$, leading to a downward bias of β_1.

A way to solve this problem of omitted variable bias is by employing fixed effects estimation methods. By demeaning all explanatory variables the firm fixed effect will disappear and the error term will not be correlated with the explanatory variables anymore, for example, if the corporate culture was time invariant it would not bias the results of the frontier variable anymore.[156] Of course this method is not suitable if unobservable time varying firm specific factors are correlated with the right hand side variables, for example the quality of a management. This would require an Instrument-Variable strategy. Unfortunately it is very difficult to find appropriate instruments at the firm level. To take care of other unobservable factors, time dummies are added. Those capture all effects which change over time but are similar for all firms, for example boom and bust periods of an economy.

The second main concern of the analysis are simultaneity issues. We cannot be sure that all explanatory variables are exogenous so a causal interpretation is impossible. For example, the estimation of average industry wages on fragmentation decisions of firms may look like:

$$Fragmentation_{it} = \beta_0 + \beta_1 average\ wages_{jt} + \cdots + \varepsilon_{ijt} \tag{5.10}$$

$$average\ wages_{jt} = \gamma_0 + \gamma_1 Fragmentation_{it} + \cdots + u_{ijt} \tag{5.11}$$

[156] This implies that also all other observable time constant factors will disappear.

According to the theory, industries with high average wages pay also higher wages for non-core activities. Therefore the incentive is higher to outsource those non-core activities and we expect β_1 in equation 5.10 to be positive. Equation 5.11 shows that this is not a one way relationship. If a firm outsources its non-core activities, the average wage in the industry can increase.[157] The crucial *ceteris paribus* assumption will not hold, and the results will lead to biased and inconsistent estimators (Pindyck and Rubinfeld, 1998, pp. 339). Even though the concept of simultaneity and omitted heterogeneity is different, simultaneity leads to the same consequences as the correlation between the explanatory variables and the error term (Deaton, 1995, p. 1825).

The best approach to deal with endogeneity issues is by using proxies for unobservables, or instruments which are highly correlated with the variable of concern but uncorrelated with the error term. Unfortunately it is very difficult to find appropriate instruments. For example, in equation 5.10 the instrument has to be highly correlated with wages but should not be affected by the fragmentation decision of a firm. Acemoğlu et al. (2007) use UK industry variables as instrument for French industry data. In our case, instead of using the average industry wage of the UK, we could use the industry wage of another European country or the US. In theory, actions of UK firms should not affect the average wage of different US industries. Still, some problems remain. On the one hand, we cannot find instruments at the firm level. Second, there could still be a correlation between the average US industry wage and the error term. A global recession can affect both the US and the UK industry wages and influence the organisational structure of a UK firm.

With fixed effects mentioned above at least some unobserved effects can be captured. A way to mitigate the endogeneity problem is by using lagged independent variables, like in equation 5.8. It is very tempting to treat those lagged variables as instruments, which are highly correlated with the explanatory variables, but uncorrelated with the

[157] We have to assume that this company is big in size, otherwise one fragmenting firm might not influence the average wage in an industry.

current error term. Unfortunately it only mitigates and does not solve the problem. Firm heterogeneity will affect the current but also lagged variables. For example, the corporate culture, which cannot be observed in the data, will affect the current organisational form but the labour productivity of the last period too. Therefore the lagged *frontier* variable, which is based on relative labour productivities of firms, is not exogenous anymore.[158] Still equation 5.8 is estimated with fixed effects and lagged independent variables. We cannot control for time-variant firm specific unobserved effects which leaves the error term being correlated with some right hand side variables. Because of this we will still interpret the coefficients as correlations and not as causal effects.

We are using continuous and discrete variables as dependent variables and even when the binomial dependent variables are employed, a linear fixed effects model will be estimated instead of non-linear estimation methods like Probit and Tobit. This is justified by the results showing that firm fixed effects are having a significant impact on the results.[159] Using a linear probability model is confronted with several problems too, for example the estimated coefficient can be outside the zero-one interval and provides a poor model for individual probabilities (Cameron and Trivedi, 2009, p. 471). Nevertheless it is a useful measure for the marginal effect of the mean firm. The straight and quick way of computation and the importance of firm heterogeneity seem to outweigh the disadvantages.[160]

[158] Deaton (1995), page 1825, explains it with an example of a production function of a farmer in a developing country: *"The combination of genuine simultaneity and heterogeneity has the further effect of ruling out the use of lags to remove the former; while it is true that the seeds have to be planted before the crop is harvested, heterogeneity across farmers will mean that seeds are not exogenous for the harvest, ..."*

[159] The importance of firm heterogeneity is captured by an example of the American car industry by Chandler (1990). Firms in the same industry and in the same country and during the same time period were following different vertical integration strategies: *"Ford remained fully vertically integrated, General Motors had a policy of controlling one-quarter of its suppliers, and Chrysler obtained nearly all of its supplies from independent producers."* (Chandler, 1990, p. 38).

[160] See Angrist and Pischke (2009).

5.4.5. Descriptive statistics

The dependent variables were already discussed extensively in chapter 4. In table 5.5 the basic descriptive statistics for the dependent variables and covariates are summarised. We show the results for the sample including all firms and the sample including firms which have had multiple plants at least once. It is possible that in the multi-plant sample also single-plant firms are included, therefore the average probability of being a multi-plant firm in the multi-plant sample is not equal to one. In general, manufacturing firms are more likely to be vertically integrated than service firms and more likely to have a dispersed production chain. The technology variables show that the average distance to the technological frontier is similar in all sectors. The heterogeneity index looks similar in the total and the multi-plant sample. This is caused by using only firms with more than twenty employees. Service industries are more heterogeneous than manufacturing firms. The industry characteristics reveal that the manufacturing industries are more concentrated than the service sectors. Average weekly wages and the R&D intensity are higher, and the degree of unionisation is lower in the tradable service sector. Regional characteristics reveal that tradable service firms are located in more agglomerated regions where the average wage is higher.

5.5. Results

All variables employed have been described above. The firm size is captured by employment and competition by the Herfindahl index. The heterogeneity measure only takes account of firms with more than 20 employees. Because of fixed effects regression age^2 instead of age will be used.[161] This section is divided into three parts, where in every stage the main results and the main robustness checks are presented.

[161] The demeaning through the within estimator leads to the same increase of age for every company in every year. Therefore it is not possible to distinguish this effect from the time fixed effects (Wooldridge, 2002, pp. 818). By using the square of age, the increase will be different for every firm in every year.

	Manufacturing		Tradable Services	
	All	MP	All	MP
Dependent variables				
Proportion of firms with multiple plants (*MP = 1*)	0.0467	0.6494	0.0159	0.6378
Proportion of firms with vertically integrated plants (*VID = 1*)	0.0236	0.3283	0.0029	0.1148
Degree of vertical integration (*vi*)	0.0012	0.0169	0.0002	0.0088
Standard Deviation	0.0161	0.0578	0.0064	0.0399
Proportion of firms with vi plants in multiple locations (*ML_v = 1*)	0.0127	0.1774	0.0018	0.0712
Average distance in meters between vi plants within firm (*dist_v*)	1,835	25,675	222.5	8,946
Standard Deviation	20,768	73,624	7,348	45,751
Explanatory variables				
Technology variables				
Age (*age*)	12.35	19.45	6.83	16.56
Standard Deviation	9.599	8.989	6.801	9.817
Heterogeneity Index (*het_ind_g20*)	0.6886	0.6693	1.1989	1.0735
Standard Deviation	0.3115	0.2672	0.5361	0.6123
Distance to the technological frontier (*frontier*)	-2.1783	-2.0052	-2.0892	-2.1251
Standard Deviation	0.9532	0.9075	0.9399	1.1410
Firm characteristics				
Number of employment (*employment*)	21.11	166.73	5.47	93.14
Standard Deviation	190.73	683.92	100.32	613.31
Turnover in thousands of GBP (*turnover*)	2,361	22,405	407.33	6,627
Standard Deviation	41,030	149,793	8,557	47,357
Labour Productivity, turnover over employment (*prod*)	80.45	103.36	77.39	109.07
Standard Deviation	439.02	373.45	1,454.04	1,536.88
Number of plants per firm (*J*)	1.1124	2.5651	1.0540	3.1684
Standard Deviation	1.3834	4.9362	10.0552	63.7012
Proportion of foreign owned firms (*foreign*)	0.0206	0.1341	0.0072	0.0590
Industry characteristics				
Herfindahl index for industry concentration (*herfindahl*)	0.0386	0.0512	0.0112	0.0143
Standard Deviation	0.0764	0.0865	0.0232	0.0273
Average weekly net industry wages (*av_bpay_ind*)	343.68	345.28	491.62	456.23
Standard Deviation	84.96	81.83	110.48	110.24
Degree of unionisation (*colag_ratio*)	0.3829	0.4133	0.2178	0.2152
Standard Deviation	0.1500	0.1494	0.0937	0.0967
In-house R&D intensity (*rad_ih_ratio*)	0.0099	0.0120	0.0150	0.0237
Standard Deviation	0.0502	0.0501	0.0926	0.1418
External R&D intensity (*rad_ex_ratio*)	0.0013	0.0014	0.0026	0.0050
Standard Deviation	0.0273	0.0255	0.0283	0.0411
Capital intensity, av. real capital stock per worker in SIC4 (*cap_int*)	24.86	28.92	90.01	110.29
Standard Deviation	71.72	90.10	72.46	77.36
Regional characteristics				
Population density in local authority (*agglom*)	1.8652	1.6872	2.4404	2.5317
Standard Deviation	2.4718	2.1893	3.1665	3.1134
Average weekly net wages in local authority (*av_bpay_lua*)	321.81	316.09	363.95	356.46
Standard Deviation	78.94	74.20	109.50	115.99

Table 5.5: Descriptive statistics for dependent and independent variables across 1998 – 2008

Stage 1: Multi-plant firms

To see which firms in which industries are more likely to have a multi-plant structure, we use the total firm sample. According to Kim (1999) becoming a multi-plant firm depends on locational and organisational factors, therefore I will include *all* explanatory variables. The analysis focuses on the degree of market power. The higher the degree of market concentration, the more likely it is to have multi-unit firms. Besides market power horizontal motives are important. According to the Proximity-Concentration trade-off the higher the capital intensity of an industry the higher is the probability of having big, concentrated firms. On the other hand, if a sector is not capital intensive, it is easier to set up a new business, because technical barriers to enter the market are low. Therefore many single-plant firms can appear. Finally, we expect that firm size and firm age is positively correlated with being a multi-plant firm. If a firm gets too big dis-economies of scale can arise because of, for example, increasing communication costs. Older firms may have better market knowledge, less restrictive budgetary constraints and a better known product which makes setting up a new plant easier.

$$\begin{aligned} MP_{ijrt} = {} & \beta_0 + \beta_1 age^2_{ijrt-1} + \beta_2 \log(employment_{ijrt-1}) + \beta_3 \log(employment^2_{ijrt-1}) + \\ & + \beta_4 foreign_{ijrt-1} + \beta_5 frontier_{ijrt-1} + \beta_6 hetero_{jt-1} + \beta_7 \log(wage_{jt-1}) + \\ & + \beta_8 concent_{jt-1} + \beta_9 R\&D_{jt-1} + \beta_{10} \log(cap.\ int_{jt-1}) + \beta_{11} \log(wage_{rt-1}) + \\ & + \beta_{12} union_{jt-1} + \beta_{13} agglom_{rt-1} + D_t + a_{ijr} + \varepsilon_{ijrt} \end{aligned} \tag{5.12}$$

The main problem of this stage is the large sample size, which is pushing `Stata` to its memory limits. While the analysis can be conducted with the full manufacturing sample we have chosen a random 30 percent sample from the tradable service sector.[162]

The base results are presented in the *base* columns of table 5.6. The coefficients look

[162] The last digit of the enterprise reference number is random. Therefore we chose three numbers and keep all firms, which end with the chosen number.

Variables	**Manufacturing** Base		Cap. Intensity		**Tradable Services** Base		Cap. Intesity	
Dep. Var.	MP		MP		MP		MP	
Hetero.	-0.0012	**	-0.0010	*	0.0009	**	0.0016	***
Frontier	0.0021	***	0.0022	***	0.0016	***	0.0019	***
Age^2	0.0000	***	0.0000	***	0.0000	***	0.0000	***
Employment	-0.0216	***	-0.0205	***	-0.0073	***	-0.0056	***
$Employment^2$	0.0138	***	0.0131	***	0.0085	***	0.0077	***
Foreign	0.0028	*	0.0037	**	0.0092	***	0.0078	***
Herfindahl	0.0090	**	0.0096	**	0.0183	**	0.0483	***
Ind. Wage	0.0031	*	0.0031	*	0.0029	**	-0.0022	
Reg. Wage	0.0009		-0.0019		-0.0007		-0.0003	
Agglomeration	0.0000		0.0001		-0.0001		-0.0001	
Cap. Intensity			0.0003	*			0.0003	
Ex. R&D	0.0147		0.0108		0.0325	**	0.0519	**
Ih. R&D	-0.0037		0.0018		-0.0083	*	-0.0084	
Unionisation	-0.0017		-0.0016		-0.0123	***	-0.0158	***
Constant	-0.0113		0.0041		-0.0056		0.0207	
Fixed effects	Yes		Yes		Yes		Yes	
Observations	1,009,570		894,503		933,263		587,203	
R-Square	.0255		.0233		.0235		.0205	

* p<0.05, ** p<0.01, *** p<0.001

Table 5.6: Base and capital intensity results for stage 1

rather small, but in general the number of multi-plant firms is rather low. Only 4.7 percent in manufacturing and 1.6 percent in tradable services are multi-plant firms. Market power seems to be an important determinant. In both sectors a higher market concentration is positively correlated with having a multi-unit structure. If the market concentration is increased by a standard deviation, then a firm will be 0.07 percentage points more likely in manufacturing and 0.04 percentage points in tradable service sector to be a multi-plant firm.[163] This is an increase by 1.5 percent in manufacturing and 2.5 percent in the tradable service sector in comparison to the average probability of becoming a multi-plant firm.[164]

The external R&D intensity of an industry has a positive impact on the probability of becoming a multi-plant firm, but the opposite sign is found for the in-house R&D intensity. Only the coefficients for the tradable service R&D intensities are statistically

[163]This values are calculated as 0.0764×0.00898 in manufacturing and 0.0232×0.0183 in tradable services.
[164]Manufacturing: 0.0007/0.0467. Tradable services: 0.0004/0.016.

significant. Those two variables could comprise of different types of knowledge capital. External R&D intensities could cover investments into marketing, which follows Kim's argument. In-house R&D intensity could be a proxy for capital intensity, which would capture economies of scale at the plant level and favour a single-plant structure. An increase of external R&D intensity by a standard deviation in the tradable service sector leads to an increase in the probability of becoming a multi-plant firm in comparison to the average probability by 5.7 percent ($(0.0283 \times 0.0325)/0.016$) and for in-house R&D a decrease of 4.6 percent ($(0.0926 \times -0.008)/0.016)$). As a robustness check we also add capital intensities to the regression results in table 5.6. The in-house R&D results are sensitive to the inclusion of a capital intensity variable. While it remains negative and turned into insignificant in the service sector, the sign changed in manufacturing. Capital intensity is positive and significant in manufacturing. Contrary to the proximity-concentration theory we find that lower capital intensities lead to more single-plant firms, even though the effect is extremely small.

As expected, larger firms and foreign firms are more likely to be multi-unit firms. Increasing the average employment size of a manufacturing firm by 10 percent will lead to an increase in the probability of getting a multi-plant firm of 0.6 percentage points. For a firm of the tradable service sector the probability will increase by 0.4 percentage points.[165] Age is statistically but not economically significant. In more technologically heterogeneous sectors it is less likely for multi-unit firms to appear in the manufacturing but more likely in the tradable service sector. If the technological industry heterogeneity increases by one standard deviation, it will lead to a 0.04 percentage point decrease in the probability of becoming a multi-unit firm in manufacturing and a 0.05 percentage point increase in tradable services.[166] If we consider the average probability this

[165]The calculation was the following: $0.01 \times (-0.0216 + 2 \times 0.0138 \times \log(21)) \times 10$ (manufacturing) and $0.01 \times (0.0085 + 2 \times 0.0092 \times \log(5.5)) \times 100$ (service sector). See footnote 171 on page 187 for a detailed explanation of how to calculate non-linear effects.

[166]These values are calculated as 0.3115×-0.0012 in manufacturing and 0.5361×0.0009.

would lead to an 0.9 percent decrease in manufacturing and a 3.1 percent increase in the service sector.[167] The closer a firm is to the technological frontier, the more likely it will be a multi-unit firm. A doubling of the proximity to the technological leader leads to a 3 percent $((0.0021 \times \log(2)/0.047)$ increase in manufacturing and a 7 percent $((0.0016 \times \log(2))/0.016)$ increase in tradable services. We do not find evidence that if headquarters are located in populated areas that firms will be more likely to be multi-plant firms. Also no statistical proof exists that higher regional wages will promote multi-unit firms.

We check the robustness of three variables. First, we use an alternative measure for technological heterogeneity. This measure uses a three year average of the productivity growth of a firm. In manufacturing, the results remain robust, but in the tradable service sector the effect of industry heterogeneity becomes insignificant. We use the C4 concentration measure instead of the Herfindahl index. The firm concentration effects remain positive and significant. Finally, to capture knowledge capital we substitute in-house R&D intensity with a scientific staff ratio. In manufacturing the variables remain insignificant. In the tradable service sector the sign remains negative but becomes significant. The results for the robustness checks are gathered in table C.7 on page 295 in the appendix.

Concluding, market concentration has a positive effect in both sectors, but seems to matter more in the tradable service sector. We also find a positive correlation for the external R&D intensity, however the results are only statistically significant for firms of the tradable service sector. Technology matters too, especially the relative distance to the technological frontier. We find that size and foreign ownership have a positive impact in being a multi-plant firm.

[167] Manufacturing: $-0.0004/0.0467$. Tradable services: $0.0005/0.016$.

Stage 2: Vertically integrated firms

The sample size can be reduced massively by keeping those firms, which have been a multi-plant firm at least once. According to our definition only multi-plant firms can be vertically integrated. Therefore the interpretation will be based on firms, which have the opportunity to be vertically integrated, for example, that they can afford to set up another local unit. A discrete and a continuous measure of vertical integration are used. We will focus on the discrete measure and compare the results then with the continuous measure. The estimated model is shown in equation 5.13.

$$
\begin{aligned}
VID_{it} = \beta_0 &+ \beta_1 age^2_{it-1} + \beta_2 \log(employment_{it-1}) + \beta_3 \log(employment^2_{it-1}) + \\
&+ \beta_4 foreign_{it-1} + \beta_5 frontier_{it-1} + \beta_6 hetero_{jt-1} + \beta_7 \log(wage_{jt-1}) + \\
&+ \beta_8 concent_{jt-1} + \beta_9 R\&D_{jt-1} + \beta_{10} union_{jt-1} + \beta_{11} agglom_{rt-1} + \\
&+ D_t + a_i + \varepsilon_{it}
\end{aligned} \tag{5.13}
$$

This stage will focus on how technology differences, knowledge capital and incomplete contracts affect the decision of a firm to be vertically integrated. The three variables capturing the first are firm age, the distance of a firm to the technological frontier and the heterogeneity of technology used in every industry. The KCM will be tested by using external and internal R&D intensities of industries. Also capital intensities of industries will show if, like Antràs and Helpman (2004) predict, a higher intensity leads to integration being more likely to happen. For taking account of the cost-savings advantages we add average industry wages and degree of unionisation. Agglomeration captures the population density in a region and is expected to have a negative impact on the probability of being integrated. In contrast to before, I exclude the average wage of a local authority from the equation, because regional wage differences should only affect spatial and not organisational fragmentation.

First results show that firm heterogeneity has a strong influence on the results. See table

Variables	**Manufacturing** Discrete		Cont.		**Tradable Services** Discrete		Cont.	
Dep. Var.	VID		VI		VID		VI	
Hetero.	-0.0111		-0.0004		-0.0162	***	-0.0015	**
Frontier	0.0070	**	0.0002		0.0046	**	0.0006	**
Age^2	-0.0000	*	-0.0000		0.0000		0.0000	***
Employment	0.0466	***	-0.0028	**	0.0385	***	0.0019	***
$Employment^2$	0.0108	***	0.0015	***	-0.0005		0.0003	***
Foreign	0.0013		0.0009		0.0007		0.0016	
Herfindahl	0.0534		0.0019		0.3407	***	0.0459	***
Ind. Wage	0.0102		0.0008		-0.0981	***	-0.0126	***
Agglomeration	-0.0002		-0.0003		-0.0026	*	-0.0005	***
Ex. R&D	0.3236	*	0.0035		0.1117		0.0212	
Ih. R&D	-0.2390	*	-0.0138		0.0684	*	0.0066	
Unionisation	-0.0304	*	-0.0031		0.0425		0.0052	
Constant	-0.0578		-0.0017		0.6362	***	0.0782	***
Fixed effects	Yes		Yes		Yes		Yes	
Observations	65,446		65,446		66,470		66,470	
R-Square	.037		.0122		.0263		.0135	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 5.7: Discrete and continuous vertical integration results for stage 2

C.8 on page 296 of the appendix for a comparison of the OLS, Probit and fixed effects estimation results.

Table 5.7 reveals the results of the analysis. The technology variables lead to the same result in both sectors. We want to highlight here again that the interpretation of the coefficients is *not causal*, because we cannot control for time-variant unobservable factors. The age coefficient is economically insignificant. This can be caused by fixed effect capturing most of the variety.

Highly significant and negative results are found for the heterogeneity measure in the tradable service sector. In manufacturing the coefficients are negative but only significant at the 10 percent significance level. A higher degree of technological heterogeneity in an industry is a better environment for fragmented firms. The magnitude of the change is different in each sector. The standard deviation of heterogeneity was 0.267 in manufacturing and 0.612 in tradable services (see table 5.5). A manufacturing firm facing a standard deviation higher industry heterogeneity level has a 0.3 percentage points

(-0.011×0.267) lower probability of being vertically integrated. For a tradable service firm it is a 1 percentage point (-0.0162×0.612) lower probability of being vertically integrated. To calculate an approximation for an elasticity measure, we compare the coefficients with the average probability of being vertically integrated. According to table 5.5 the mean value in manufacturing is 0.33 and in the tradable service sector 0.115. In manufacturing we observe a 0.9 percent (0.001/0.33) lower probability relative to the average industry, which is a small difference. In tradable services it is around 9 percent (0.01/0.11).[168]

The technological frontier variable is highly significant and positive in both sectors. A firm being a technological leader in a sector is more likely to be vertically integrated — a result opposite to what we have expected. Internal decision power delegation cannot be compared with external decentralisation decisions. A technological leader may require intermediate inputs which can be produced internally and not sourced by unrelated affiliates, because they do not possess the technology to produce those intermediaries. This result is highly significant even after controlling for knowledge capital. Doubling the proximity to the technological frontier leads to an increase in the probability of being integrated by 1.5 percent ($0.007 \times \log(2)/0.33$) in manufacturing and by 1.8 percent ($0.0046 \times \log(2)/0.115$) in the tradable service sector.[169]

The result of the *external R&D* is what we have expected. Firms in R&D intensive sectors are more likely to be vertically integrated. This result is significant for manufacturing but insignificant for the services sector. Descriptive statistics from table 5.5 show that the mean R&D intensity is rather low (0.0014 in manufacturing and 0.005

[168] Acemoğlu et al. (2006) calculate the effect by multiplying the coefficient with the heterogeneity mean value instead of standard deviation. Their 'elasticity' was 23 percent for the manufacturing sector. Their estimated coefficient was 0.251, the mean industry heterogeneity was 0.275 and the base 0.3. If we follow Acemoğlu's calculation we get a value of 2.4 percent for manufacturing and 19 percent for tradable service firms. Our elasticities are much smaller, but, in contrast to our data, Acemoğlu et al. look only at power decentralisation *within* a firm. Therefore we observe a weaker effect of an increase in industry heterogeneity on organisational fragmentation.

[169] Acemoğlu et al. (2006) calculated an effect of 37 percent, but again, this percentage is related with firm internal delegation decisions.

in tradable services) and confronted with relatively high standard deviations (0.026 in manufacturing and 0.041 in tradable services). Therefore a manufacturing firm in an industry with a standard deviation higher R&D intensity will experience a 0.8 percentage point (0.324×0.026) higher probability of becoming vertically integrated. In the tradable service sector an increase of a standard deviation will lead to a 0.5 percentage points (0.112×0.041) higher probability of being vertically integrated. The latter relationship is not statistically significant. An unexpected result appears for *in-house R&D* expenditures for manufacturing firms. Firms in a more in-house R&D intensive sector are more likely to be fragmented, which offers a different result than theory would suggest. The result in the tradable service sector is positive and significant. The in-house R&D intensities are higher than the external R&D intensities. A firm in an industry with a standard deviation higher in-house R&D intensity has 1.2 percentage points (-0.24×0.05) lower probability of being vertically integrated in manufacturing and 1 percentage point (0.068×0.14) higher probability in the tradable service sector.

How is it possible that R&D expenditures may lead to a decrease in the probability of becoming vertically integrated? A theoretical explanation can be by Antràs and Helpman (2004) which conclude that headquarters service intensive sectors would prefer integration of intermediate input production to outsourcing. This argument is based on the theory of incomplete contracts. However Grossman and Hart (1986) argue, in a more general way, that the best outcome for a firm is gained if the ownership is allocated to the company, for which the ex-ante investments are more crucial.[170] An increase in R&D expenditures might change the input mix of production. Therefore there could be a change of priority

[170] For example, if the component input is crucial for a final product it is better to give the component supplier the residual rights. We can link this statement to the results of Acemoğlu et al. (2009). If backward vertical integration is considered, and the downstream plant is R&D intensive, a firm is better off by having another intermediate inputs supplying plant. But it could be the case that the intermediate input suppliers are part of the R&D intensive production stages. Then there is a higher probability of an upstream local unit being forward vertically integrated but not backward. Because our firm measure is based on local units, a firm which has a backward integrated local unit has by definition also a forward integrated local unit. Therefore this explanation cannot be used to explain the observed pattern.

for ex-ante investments, leading to a higher propensity of fragmentation than integration. Another possible explanation is that R&D might not be able to capture the headquarters service intensity as suggested by Antràs and Helpman (2004). For example, while external R&D captures headquarters services and knowledge capital, like blue-prints, marketing strategies, etc., we are thinking of, in-house R&D may capture the capital intensity of a firm. Capital intensity can be higher in those sectors, which have already outsourced the labour intensive production stages, which pushed the capital-labour ratio up. To analyse these considerations we will conduct two robustness checks by adding actual capital intensity and looking at a firm specific R&D intensity. Another explanation could be that the high correlation between external and internal R&D leads to a collinearity-problem.

Agglomeration has a negative impact on the probability of being vertically integrated. This effect is only significant in the service sector.[171] *Size* matters in all sectors. There is a positive effect in the service sector and a positive non-linear effect in manufacturing.[172]

[171] To illustrate the effect of population density, consider Nottingham with a 3.62 people per square meter and Inner London with 8.98 people per square meter in 2002 (ONS, 2004a,b). The population density difference is 5.36. Therefore a tradable service firm in Nottingham with London's population density would be expected to have a 1.4 percentage points (-0.0026×5.36) lower probability to be vertically integrated than a firm in actual Nottingham. If the base probability of vertical integration is considered, it would mean that the probability will decrease by 12 percent (0.014/0.115) percent.

[172] The interpretation of the coefficients has to be done carefully, because, while the dependent variable is a dummy, the independent variables are measured in Log. Starting with the tradable service sector, the coefficient 0.0385 means that a one percent higher employment is correlated with a 0.0385 percentage points (0.0385/100) higher probability of being vertically integrated. The mean employment in the tradable service sector is around 93. A ten percent, or 9 workers, larger firm will experience a 0.39 percentage points increase in becoming vertically integrated. Because of the non-linearity the effect is larger in the manufacturing sector. The mean employment size in manufacturing is 167. A one percentage increase at this size is correlated with an increase in the probability of becoming vertically integrated of 0.16 percentage points $(0.01 \times (0.0466 + 2 \times 0.0108 \times \log(167))$ This calculation requires further explanation. The standard equation is $VI = \beta_0 + \beta_1 \log(emp) + \beta_2[\log(emp)]^2 + u$, ignoring now all other covariates and indices, which will not influence the results. To calculate the marginal effect this equation has to be differentiated with regards to $\log(emp)$. This leads to $\Delta VI/\Delta \log(emp) = \beta_1 + 2 \times \beta_2 \log(emp)$. Because the estimated model is a lin-log model, the interpretation of a percentage change of employment affecting a percentage point change in the probability of being vertically integrated requires a division by 100. The marginal of a specific employment size is then calculated as $\Delta VI = 0.01 \times [\beta_1 + 2 \times \beta_2 \times \log(emp)] \times \%\Delta emp$. For example, we would expect a firm, which is ten percent, or 17 workers, larger than the mean firm, to have a 1.6 percent higher probability of being vertically integrated.

Foreign ownership is positively but not significantly correlated with being vertically integrated. Girma and Görg (2004) may be right by assuming that foreign owned local units are by definition more specialised and source additional intermediate inputs from other local units of the same firm. Market concentration has only a significant impact for tradable services. A higher degree of competition is positively correlated with outsourcing.

Finally, *cost-savings* motives seem to matter in tradable services. A higher average wage in an industry leads to a higher probability of becoming fragmented.[173] Unionisation shows that a higher degree has a significant negative impact in the manufacturing and a positive insignificant impact in the tradable service sector. As Girma and Görg (2004) point out, even though wages might not be different if a sector is highly unionised or not, other costs can arise for a company, therefore fragmentation seems to be more likely. Examples are regulated working hours, difficulties to make employees redundant, etc. This seems to be the case in the manufacturing sector. The negative sign of the tradable service sector can be explained that stronger trade unions can also prevent firms to outsource to different countries which could cause a higher probability of being vertically integrated.

Concluding this section, technology matters. With the exception of age, the technological variables are important. The calculations above show that the coefficients are rather similar, but the effect on the base probability seems to be stronger in the service sector. The results for the R&D intensities are ambiguous. To check the robustness of those results, we will use a continuous vertical integration measure, a model with physical capital intensities and estimations using the BERD sample.

[173] For example, a firm in an industry with an average wage of ten percent (£46) higher than in the mean industry (£456) will be a 1 percentage point less likely to be vertically integrated ($0.01 \times (-0.0981) \times 10$).

Continuous measure

We substitute the discrete integration measure with a continuous measure. The average degree of vertical integration in manufacturing is 1.7 percent and 0.88 in the tradable service sector. The distribution is extremely skewed, with many firms having a low degree of vertical integration and only a few with higher degrees. As shown in table 5.7 this will lead to relatively small absolute effects. The signs are nearly identical to the discrete case, but in the manufacturing sector less significant coefficients appear. Only the size coefficient is still significant. With the exception of the in-house R&D coefficient the significance of the results remains in the tradable service sector.[174]

Capital stock and the BERD sample

As a robustness check for headquarters service intensity we use the capital intensity of an industry. The ARD allows us to calculate the real capital stock of an industry. Capital intensity is measured as real capital stock per worker. Data is only available for the period 1998 – 2006 and results are presented in table 5.8. Even though the panel is two years shorter, the results change only marginally from the baseline results. The capital stock variable has a negative but insignificant sign in manufacturing. The R&D variables are also not affected. In the service sector, the capital stock variable is positive but insignificant. The R&D variables are sensitive to the inclusion. Both external and internal R&D coefficients remain positive, but while the in-house R&D coefficient turns insignificant and smaller, the external R&D coefficient becomes significant and larger.

One main problem of R&D expenditures is that only few firms actually engage in R&D, therefore the R&D coefficients are mostly insignificant or may cause unexpected results. A smaller sample will be employed with firms for which firm level R&D data from the

[174] To illustrate the small absolute changes, the distance to the technological frontier will be considered for the tradable service sector. The coefficient is 0.0006. If a firm is twice as close to the technological frontier, then we would expect a 0.04 percentage point ($0.0006 \times \log(2)$) lower degree of vertical integration. That means 0.04 percent more of intermediate inputs will be sourced from the market. This seems to be very little, but if the change is compared with the average degree of vertical integration, this would represent a 4.5 percent change (0.0004/0.0088).

Variables	Manufacturing Cap. Stock		Manufacturing BERD		Tradable Services Cap. Stock		Tradable Services BERD	
Dep. Var.	VID		VID		VID		VID	
Hetero.	-0.0139	*	-0.0003		-0.0173	***	-0.0025	
Frontier	0.0065	*	0.0015		0.0046	**	0.0012	
Age^2	-0.0000	*	0.0001	***	-0.0000		-0.0000	
Employment	0.0367	***	-0.0264	*	0.0304	***	-0.0086	*
Employment^2	0.0112	***	0.0129	***	0.0000		0.0047	***
Foreign	-0.0007		0.0128		-0.0027		-0.0155	*
Herfindahl	0.0671	*	0.0562		0.4356	***	-0.0246	
Ind. Wage	0.0000		0.0096		-0.0911	***	-0.0020	
Agglomeration	0.0003		0.0027		-0.0038	**	-0.0017	
Cap. Intensity	-0.0008				0.0040			
Ex. R&D	0.3968	*	-0.0010		0.3062	*	-0.0000	
Ih. R&D	-0.2460	*	0.0003		0.0259		0.0000	
Unionisation	-0.0358	*	0.0088		0.0260		0.0291	
Constant	0.0345		-0.0838		0.5190	***	0.0382	
Fixed effects	Yes		Yes		Yes		Yes	
Observations	57,521		24,770		49,831		17,820	
R-Square	.0352		.016		.0225		.00513	

* p<0.05, ** p<0.01, *** p<0.001

Table 5.8: Capital stock and BERD sample results for stage 2

BERD is available. The description of how the sample was selected can be found on page 155. The same estimation methods will be used. The results are presented in table 5.8.

The signs of the technology variables are identical to the analysis above, even though they are not significant anymore. The significance of the R&D expenditures disappeared. There is no evidence that R&D expenditure are affecting the decision of a firm to become vertically integrated or not. One explanation is sample selection bias. In the BERD sample only firms spending money on R&D are included. By neglecting other firms without R&D expenditures the effect of R&D on the probability of being vertically integrated may be understated. Another explanation is that knowledge capital factors like advertisement and reputation are not included in purely R&D measures. Also R&D expenditures are flow variables, but to be more precise, the knowledge capital stock should be considered for the decision of being vertically integrated or not.

Further robustness checks

We also conduct a variety of robustness checks, which are all presented in the appendix on pages 298 and 299. In general the results are robust independent of the covariates used. Here we will only discuss the sensitive cases. Instead of using the heterogeneity measure based on firms with more than 20 employees a heterogeneity measure with a three year average growth rate was employed. The results do not change in the manufacturing sector. In the service sector, additionally to the disappearing significance, also the sign has changed. Therefore this result is sensitive to which measure has been used. However, as explained above in section 5.4.2 using all firms creates a very noisy measure of heterogeneity and therefore we stick to the restricted measure.

Instead of in-house R&D intensity a scientific worker ratio was used. We still find a negative, but this time insignificant, coefficient in manufacturing. We get the same result in the tradable service sector. External R&D are sensitive to that change. In the tradable service sector the coefficients become significant and more than twice as large as in the baseline regression.

Stage 3: Multi-location firms

In this stage the distance between local units which produce intermediate inputs and headquarters are analysed. We consider only local units which are vertically linked to the headquarters. The multi-plant sample is the foundation of the estimation. On the one hand, a discrete multi-location dummy and, on the other hand, a continuous measure with average distance between headquarters and local units are available. The continuous measure will be used as the main indicator for the geographical distribution of a company, mainly because it can be the case that the dummy is rather imprecise.

Which vertically integrated firms will be spatially concentrated or dispersed? Because we use the multi-plant sample we expect all technology and knowledge capital variables to have a positive effect on firms being geographically dispersed. Additionally, an average wage per region variable was added to capture factor price differences. We expect firms having headquarters in areas with high average wages and in agglomerated regions to be more likely to be dispersed. Equation 5.14 shows the estimated model.

$$\begin{aligned} DIv_{ijrt} = {} & \beta_0 + \beta_1 age_{ijrt-1} + \beta_2 \log\left(employment_{ijrt-1}\right) + \beta_3 size^2_{ijrt-1} + \beta_4 foreign_{ijrt-1} + \\ & + \beta_5 frontier_{ijrt-1} + \beta_6 hetero_{jt-1} + \beta_7 \log\left(wage_{jt-1}\right) + \beta_8 concent_{jt-1} + \\ & + \beta_9 R\&D_{jt-1} + \beta_{10} \log\left(wage_{rt-1}\right) + \beta_{11} union_{jt-1} + \beta_{12} agglom_{rt-1} + \\ & + D_t + a_{ijr} + \varepsilon_{ijrt} \end{aligned} \tag{5.14}$$

As in stage 2, a comparison between OLS and fixed effects regression reveals that firm heterogeneity matters (see table C.11 on page 300 in the appendix). Table 5.9 compares the results of a fixed effects regression with lagged covariates for the manufacturing and the tradable service sector. Because we have also non-vertically integrated firms in the sample, the continuous distance measure will be left censored at zero. Censoring can lead to biased and inconsistent estimators.[175]

The FPM is based on manufacturing firms which produce heterogeneous goods requiring headquarters services and labour intensive intermediate goods. We expect a UK company with its headquarters in an area with high factor prices to shift labour and capital intensive production stages into cheaper areas. As a proxy for factor prices the average weekly net wages are used. We do not have data for capital costs, so we hope to capture capital price differences with this variable. We do not find evidence that factor price differences matter within the UK. The coefficients have even a negative sign.[176]

[175] A way to deal with this problem is by using a Tobit model. This has not been conducted yet but is planned to be done for future modifications of this chapter.

[176] A firm in a region with a 10 percent higher wage will have firms which are on average 0.37km $(-3.702/100) \times 10)$ less dispersed. A similar effect remains in the tradable service sector. High wages can be an indicator for a higher number of skilled people, which are necessary for tradable services. Therefore local units might be concentrated in those regions.

	Manufacturing			Tradable Services		
Variables	Cont. Level	Discrete	Cont. LOG	Cont. Level	Discrete	Cont. LOG
Dep. Var.	DIv	MLv	log(DIv)	DIv	MLv	log(DIv)
Hetero.	-335.2	-0.0039	-0.0262	-1,993 **	-0.0121 ***	-0.0246
Frontier	1,048 **	0.0063 **	-0.0026	1,153 ***	0.0054 ***	0.0095
Age^2	8.92 ***	-0.0000	0.0001	2.0	0.0000	0.0000
Employment	-4,659 ***	-0.0132 *	-0.0759	2,659 ***	0.0199 ***	-0.0133
$Employment^2$	2,302 ***	0.0130 ***	0.0140 **	178	0.0013 **	0.0104
Foreign	-1,026	0.0127 *	-0.0267	-275.4	0.0051	-0.0417
Herfindahl	1,992	0.0724 **	0.0098	37,311 **	0.2370 ***	-0.5309
Ind. Wage	-422	-0.0081	0.0255	-6,385 **	-0.0636 ***	-0.1584
Reg. Wage	-3,702	-0.0075	0.0906	-3,394	-0.0163	-0.1779
Agglomeration	339.3	-0.0006	-0.0200 *	-459.2 **	-0.0027 **	-0.0263 *
Ex. R&D	-18,999	0.0274	0.0360	-1,822	0.0748	-1.4344 *
Ih. R&D	4,490	-0.0276	0.0201	15,325 **	0.0434	0.4759 *
Unionisation	-4,066	-0.0058	-0.0403	15,468 ***	0.0282	0.2381
Constant	26,858	0.1163	9.6827 ***	63,374 ***	0.5128 ***	12.0999 ***
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	65,446	65,446	17,065	66,470	66,470	6,360
R-Square	.0146	.0228	.00509	.0124	.0192	.0232

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 5.9: Discrete and continuous vertical integration results for stage 3

The second regional factor, agglomeration, has a significant negative coefficient in the service sector. In more agglomerated areas firms are more likely to be concentrated. If the population density of Nottingham is increased by 5.36 to reach the population density of London, then firms will be 2.5km (-0.459×5.36) less dispersed in the tradable service sector. The mean dispersion is 8.9km in tradable services. An increase by 2.5km represents a 28 percent increase.

Industry heterogeneity and the distance to the technological frontier have the opposite sign in both sectors. This was expected because only firms which are vertically integrated can have a positive rate of dispersion. To double the proximity to the technological frontier leads to firms to be less dispersed by 0.73km ($1.05 \times \log(2)$) in manufacturing and by 0.8km ($1.153 \times \log(2)$) in the tradable service sector. The R&D variables have large but insignificant effects.

Size matters again. There is a non-quadratic employment coefficient in the manufacturing.[177] A positive size effect is also found in the tradable service sector. Market concentration has a significant positive effect on the tradable service sector[178] and we find also an insignificant positive effect in manufacturing. Average industry wages have a significant negative sign in the service sector. This variable affects the dispersion via the vertical integration channel. The higher the industry wages, the more likely it will be for a firm to fragment the production chain leading to a more spatially concentrated firm. A firm within a sector with ten percent higher average wages will be 0.6km less dispersed in the tradable service sector. Finally the degree of unionisation matters for the tradable service sector. An increase by one standard deviation, which is around ten

[177] The minimum is already reached after 2.75 employees ($\exp[4.659/(2 \times 2.302)]$). If the average firm with 167 employees in manufacturing is compared with a ten percent larger firm, then the latter firm will be 1.9km ($0.01 \times [-4.659 + 2 \times 2.302 \times \log(167)] \times 10 = 1.9$) more dispersed.

[178] A firm in a standard deviation more concentrated industry, will be on average 1km more dispersed. Competition is a good example to illustrate the causality problem. On the one hand, it is assumed that in industries with a higher market concentration firms have economic profits so they can easier access other markets. On the other hand, also the higher dispersion and crowding out of smaller competitors causes higher market concentration.

percentage points, will be correlated with a 1.5km higher degree of dispersion. As a first robustness check we use a multi-location dummy as dependent variable.

Discrete measure

The dependent variable is a multi-location dummy, indicating if a firm is active in multiple local authorities. We find support for the results of the continuous measure. The coefficient of regional wages remains insignificant and negative. Even if a manufacturing firm is active in a location with twice as high regional wages, the probability of being a multi-location firm will decrease by 0.005 percentage points, which is, calculated at the base probability of being a integrated multi-location firm of 0.18, around 2.8 percent.

The importance of technology is supported by this robustness check. The closer a company is to the technological frontier the likelier it is to be located in multiple locations. For more productive firms it is easier to overcome the fixed costs of setting up a new intermediate input supplying firm. The technological heterogeneity of a sector has always a negative effect on the probability of being a multi-location firm and distance, but is only significant for the tradable service sector. The channel for this result is the same like in stage two of our analysis. The bigger a company is, the higher is the marginal probability of being a multi-location firm. Competition leads to a lower probability of having vertically integrated local units in different regions. This effect is much larger in the tradable service sector.

Log-model

In our sample a firm can only be spatially fragmented if it has vertically integrated local units. To identify the factors, which are influencing the spatial distribution of vertically integrated firms and not the probability of becoming vertically integrated, we keep in this sample only vertically integrated local units. By taking the Log of distance only vertically integrated firms are kept and the results can be interpreted as elasticities. The cost of this approach is that many observations will be dropped. Also those results are presented in table 5.9. The factor price differences remain insignificant but are now positive in the manufacturing sector. A ten percent higher average wage in a local authority is related with a 0.9 percent higher degree of spatial fragmentation. There is no statistical significance.

The technological variables have small and insignificant coefficients. They do not matter for spatial fragmentation. R&D expenditures have relatively large coefficients, but are only significant in the tradable service sector. According to Brainard (1997) economies of scale at the firm level are based on R&D activities. The higher those economies of scale at the firm level are, the lower will be the costs to produce in the local units and therefore the more likely it will be for a firm to set up other plants. This can explain the positive impact of R&D. A negative effect can happen if R&D intensity is correlated with capital intensity. Setting up a new plant can be very expensive, which can reduce the probability to establish another plant. Both effects arise, but to find out why the external and in-house R&D have different signs which are exactly the opposite in the manufacturing sector requires more information about what kind of R&D investments are actually included in each category. Size matters again in the manufacturing sector. In the tradable service sector a significant correlation cannot be observed.

Additional robustness checks include the C4 concentration measure, scientific employment ration, the technological distance to the most productive firm and a 3 year average growth heterogeneity measure. The results are presented in the appendix on page 301. In the tradable service sector the effect of technological heterogeneity depends on the measure chosen. While we have a negative effect if we use the measure based on firms with more than 20 employees, a significant positive effect appears if the 3 year average measure has been chosen. In manufacturing the R&D intensities are sensitive to the chosen in-house R&D measure. The results remain insignificant but have opposite signs.

To summarise this section, for manufacturing it seems that the main driver for having a more dispersed production chain are relative productivity, firm size and market power. Only if a firm is large enough it can afford setting up local units in multiple locations. Even though we just look at the spatial distribution within the UK, relatively more productive firms (firms which are closer to the technological frontier) can afford setting up vertically integrated plants in more dispersed regions. Additionally, we find for the tradable service sector that agglomeration matters. A firm which has its headquarters in an agglomerated region does not have to source intermediate inputs from other locations.

5.6. Conclusion

The purpose of this chapter was to test the predictions of many common theories about the organisational structure of firms. Specifically we tested the effect of technology based on the model by Acemoğlu et al. (2007) and the effect of knowledge capital on the organisational fragmentation of firms. The effect of factor price differences on spatial fragmentation was tested as well. The analysis was conducted for two different samples, the manufacturing and the tradable service sector using a large sample of UK firms. Firm fixed effects estimation methods were used which had a significant impact on the results. Many significant coefficients of the Probit and the Linear Probability model turned out to have a different sign or to be significant/insignificant after applying firm fixed effects. Therefore ignoring firm heterogeneity can produce misleading results. However, fixed effect models face certain limitations. The key problem is that identification is driven only by within-firm changes of y and x. These changes can be very small and measurement error may lead to downwardly biased coefficients.

In the first stage of the analysis we looked at what factors can influence the probability of a firm to become a multi-unit firm. Market concentration has a positive effect in both sectors, but seems to matter more in the tradable service sector. While we find a small and significant impact of capital intensity in manufacturing, external R&D intensity, which captures partly economies of scale at the firm level, has a significant positive effect in the tradable service sector. Technology matters. While firms closer to the technological frontier are more likely to become a multi-plant firm, independent of the sector, we find different effects for the technological industry heterogeneity. In more heterogeneous manufacturing industries we will find less multi-plant firms. The opposite is true for the tradable service sector.

In the second stage we analysed the impact of technological variables, knowledge capital and incomplete contracts on the decision of a firm to vertically integrate. Technology has a significant effect in every sector. The closer firms are to the technological frontier of a sector, the higher is the probability of being vertically integrated. External intermediate input suppliers may not be able to supply the demanded inputs, because they do not possess the suitable technology yet. This result is different to the delegation idea of Acemoğlu et al. (2007). The more technologically heterogeneous an industry is, the less likely it will be integrated. This result is in accordance to Acemoğlu et al. (2007). It is difficult to copy other firms, because not many firms have used the right way to implement the correct technology. It might be better to source from a specialised outside supplier to enjoy a more efficient technology. R&D intensities, to capture knowledge capital, is positively correlated with being vertically integrated in the tradable service sector, even though we do not find many significant coefficients. One explanation could be that a higher degree of knowledge capital could lead to moral hazard of outside suppliers, therefore firms will prefer to keep production stages internally. An unexpected result was revealed by R&D intensities in the manufacturing sector. External R&D intensity is positively correlated with being vertically integrated, in-house R&D negatively. One explanation could be that the latter affects the possibility of being forward vertically integrated, but, because our measure is focused on backward integration, this type of integration is not captured.

In the third stage we focused on the geographical distribution of the internal production chain of a firm. Our check for factor price differences, the average wage in the region of the headquarters, did not find an impact on the dispersion of UK firms. Knowledge capital cannot explain the spatial distribution. Few significant results appear for firms of the manufacturing sector. This can be caused by not being able to capture the international dimension of firms. Even without the international dimension, we still can identify which firms are more likely to be dispersed: Large firms, which are close to the technological frontier and are in a concentrated market. Only large firms can afford sourcing from different regions, and, as being a technological leader implies that firms have better managers, those firms will be more suitable to coordinate a more dispersed production. We also find that agglomeration has a positive impact in the tradable service sector.

6. The Effects of Fragmentation on Employment and Productivity

6.1. Introduction

The closing down of a plant attracts a lot of attention in the media. For example: "*400 jobs to go at zinc works*" (BBC, 18/02/03)[179], "*Cadbury's Bristol plant to close by 2011*" (BBC, 09/02/10)[180], "*302 jobs lost as factory closes*" (BBC, 04/06/09)[181], "*Chocolate plant closure is grim news, says local MP*" (The Telegraph, 11/12/10)[182] and "*Pfizer to close Viagra research site, putting 2,400 UK jobs at risk*" (The Telegraph, 01/02/11)[183]. The main worry is that all the jobs of a closed plant will be lost. Is that necessarily the case? The answer is no. For example, the chocolate plant of Nestle in Castleford, West Yorkshire, employed 210 people. The production will be moved to other plants in Halifax and Newcastle, which can create up to 120 new posts. The total employment effect (−90) can be less than the direct employment effect (−210). This effect may vary if a horizontal or vertical local unit has been closed. Here we have an example of a closure of a horizontal local unit.

What can be expected from closing a vertically integrated plant? Examples can be the shutting down of the zinc producing plant, or closing parts of the R&D site of Pfizer. We expect that some jobs might move to other plants of the firm, which should increase employment in the remaining plants. In contrast to before we also expect a specialisation effect to appear. By fragmenting the production, firms will focus more on their core activities and will offer new jobs in that area. This should lead to an increase

[179] Available at `http://news.bbc.co.uk/1/hi/england/2775051.stm`, access on 11/10/11.
[180] Available at `http://news.bbc.co.uk/1/hi/8507066.stm`, access on 11/10/11.
[181] Available at `http://news.bbc.co.uk/1/hi/wales/north_east/8081186.stm`, access on 11/10/11.
[182] Available at `http://www.telegraph.co.uk/finance/jobs/8196068/Chocolate-plant-closure-is-grim-news-says-local-MP.html`, access on 11/10/11.
[183] Available at `http://www.telegraph.co.uk/finance/newsbysector/pharmaceuticalsandchemicals/8296725/Pfizer-to-close-Viagra-research-site-putting-2400-UK-jobs-at-risk.html`, access on 11/10/11.

in productivity and mitigate or even outweigh the employment losses through the closure of the plant.

We will put our focus on fragmentation, or, to put it differently, on the closure or selling of vertically integrated local units. As we will see below the vast majority of exiting plants is actually shutting down. The employment effects of selling a local unit or to close it can be different. If the plant is sold there will be less pressure on the firm to shift workers to other plants of the same firm, because the workers of the sold-off plant will not necessarily be made redundant. The vast majority of exiting local units is shutting down. Possible explanations for this can be that firms do not want to leave parts of their knowledge capital to other firms. Another explanation can be that the least efficient plants are closed, therefore the demand for this plant might be very low. If the least productive local units are exiting the firm, then we expect the productivity of the firm to increase.

We assume that, if a plant producing intermediate inputs is *exiting* the firm, the intermediate inputs will be sourced from the market, which we refer to as organisational fragmentation. The effect on firm level employment can be ambiguous. For example, factor-proportion models predict, in an international framework, that those production stages which require an input factor which is relatively abundant in the other region will be moved abroad. While the labour intensive parts might be off-shored to India, the firm will start specialising in the capital and headquarters services intensive part of the production process. The specialisation will create new jobs, which could outweigh the previous job losses. To see if this effect actually appears, a differentiation between short- and long-run effects is necessary. This chapter will analyse if closing a vertically integrated plant actually leads to a reduction of firm employment in the short- and long-run. The first research question of this chapter will be:

> *What are the firm level employment effects of fragmentation?*

Furthermore we assume that this specialisation should lead to an increase in the labour productivity of a firm. For example, a manufacturing firm is providing in-house IT services. By focusing on what the company is good at (producing goods) and letting a specialised outside supplier taking care of the IT services, the productivity of the manufacturing firm should increase. Of course, a positive effect is also expected if the least efficient plant has been closed. This leads to the second research question:

Does fragmentation lead to an increase in labour productivity?

Fragmentation in this chapter is defined as a firm which owns a forward vertically integrated plant closing that plant. A plant is forward vertically integrated if another plant of the same firm exists, which is demanding the former plant's output. We find those production linkages by using UK input-output tables. We describe the derivation of this measure precisely on pages 114*ff* of in chapter 4.

The idea behind the employment effects is summarised in figure 6.1. The Business Structure Database (BSD) contains information at the firm and at the local unit level, where the total firm employment is calculated by adding up the employment of all local units. Let us assume that company A consists of four local units: local unit 1 represents the headquarters, local unit 2 a vertically integrated plant, local unit 3 another bigger vertically integrated local unit and, finally, local unit 4 a non vertically integrated affiliate. In period 1 the total employment of the company will be 95. At the end of period 1, local unit 2 is shut down. The total change in employment will be decomposed in a direct and indirect employment effect.

$$\text{Total Effect} = \text{Direct Effect} + \text{Indirect Effect} \tag{6.1}$$

$$\text{Direct Effect} = \Delta L_2 = -L_2 \tag{6.2}$$

$$\text{Indirect Effect} = \Delta L_1 + \Delta L_3 + \Delta L_4 \tag{6.3}$$

The direct employment effect consists of the loss of jobs in the exiting plant. In our example the direct effect would be $\Delta L_2 = -10$. The indirect effects are captured by the change in employment in all other plants, which would be $\Delta L_1 + \Delta L_3 + \Delta L_4$. The direct effect is always negative, but the indirect effects can be positive or negative. There are several reasons for expecting a *positive* indirect effect. For example, if a firm is specialising it will increase its employment needed for the core activities. If a firm is part of a sector with strong labour unions, jobs of the exiting plants may be transferred to other local units. A company might also be afraid of losing important human capital and therefore keep the experienced workers of the closing plant within the firm. However, the indirect effect might also be *negative*. For example, a firm having several local units producing complementary intermediate inputs is closing down one if its plants. Outsourcing to an outside supplier implies that intermediate inputs are now sourced from a more efficient source. This can decrease the demand for the complementary inputs, which will lead to a negative indirect employment effect. The size of the indirect effect is expected to change over time. Two possible short-run scenarios are:

Scenario 1: After closing local unit 2 all ten jobs are lost (direct effect). If there is no or just a small indirect effect, the total employment effect will be negative and approximately equal to the direct effect.

Scenario 2: New jobs might be created or workers can be transferred from the exiting plants to the remaining local units. This can lead to large positive indirect effects, which can mitigate the loss from the direct effect.[184]

It can be the case that the long-run indirect effects are different from the short-run effects. We will build on the two short-run examples.

Scenario 1a: After scenario 1 had happened, enterprise A started to specialise and the

[184] It would be very interesting to see if new workers are hired or old workers are just moved to the remaining local units. Unfortunately we cannot differentiate in our data if the new jobs are taken by existing employees or new employees to the firm.

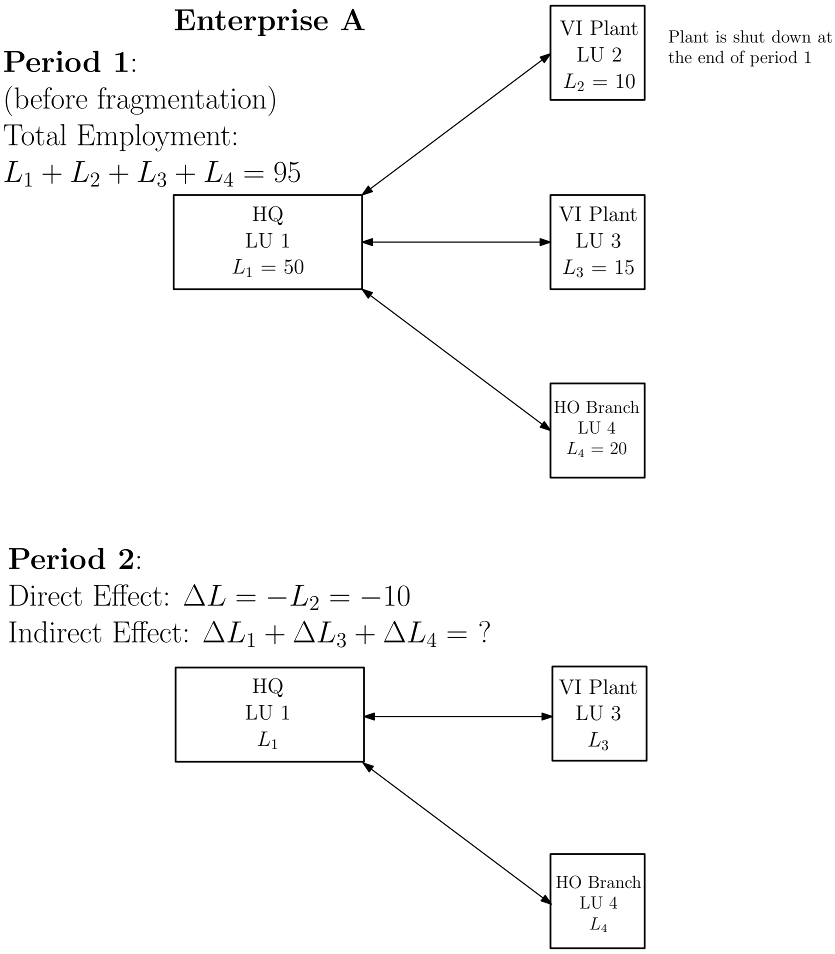


Figure 6.1: Stylised example of employment effects of fragmentation

labour demand of the other local units started to increase. Through the specialisation, the firm gets more competitive and therefore will increase its production further. This will push employment even further up. In theory, the indirect effect can outweigh the direct effect and a positive total employment effect may arise.

Scenario 2a: Scenario 2 happened in the short-run. This could be caused by trade unions or legal difficulties to make employees redundant immediately. After a while a firm can find other ways to reduce employment, for example by not hiring new workers for retired workers. Therefore the indirect effect gets smaller over time and might disappear completely.

Those scenarios show that several possibilities exist how firm level employment will develop over time. All of those scenarios are capturing *internal* firm effects. What are the external effects on the whole economy? First, N_2 can be transferred to other firms. The effect of the transfer can be ambiguous. If jobs are transferred to firms abroad, then a negative external effect can arise. Second, fragmentation can lead to an increase in efficiency and result in a higher output of the firm. The higher output requires more intermediate inputs from the outsourced industries. This can lead to an increase in the employment in the outsourced industries and create a positive external effect on domestic employment. However, in this thesis we consider only the effects of fragmentation on employment and productivity within the firm, and ignore spillover effects on other firms in the industry or linked industries.

The productivity measure that we use requires a more detailed discussion. In order to calculate productivity, we require a measure of output. Unfortunately, sales are only measured at the firm level (not at the plant level) so the only measure of productivity we can use is a sales per employee measure at the firm level. The differentiation between direct and indirect effects is not possible, because only the total effect can be captured. Ideally we should use a total factor productivity measure, but, because we only have a measure of one input (labour), we cannot derive it. Labour productivity is the best proxy for productivity we can derive from the data available. We expect that closing a plant will decrease sales in the short-run, but through higher efficiency we expect sales to recover and to increase over time. The change in sales and employment can be used to identify the change in labour productivity. We expect fragmentation to cause an increase in labour productivity.

The main database employed is the BSD in connection with the Annual Survey of Hours and Earnings (ASHE), Business Enterprise Research and Development (BERD) database and the National Statistics Postcode Directory (NSPD). The BSD only includes data for plants and firms located in the United Kingdom, but this is not necessarily a restriction for the analysis of this topic. We do not look at the employment effects at the country level, only at the firm level. Therefore if jobs are moved abroad or just to another domestic company will not affect our results.

The closest related literature is about offshoring and outsourcing, which offer ambiguous results on the effect of fragmentation on firm level employment. Biscourp and Kramarz (2007) find a negative impact of outsourcing on firm level employment. In contrast Hijzen et al. (2011), Ando and Kimura (2007) and Hijzen et al. (2009) cannot find evidence for a negative effect and even find evidence that fragmenting firms are experiencing a larger employment growth in comparison to non-fragmenting firms.

Few papers discuss the effects of fragmentation on productivity. In general, outsourcing of services will have a positive effect on productivity of manufacturing firms (Fixler and Siegel, 1999; ten Raa and Wolff, 2001; Girma and Görg, 2004), even though Görzig and Stephan (2002) find only a positive impact in the long-run, Girma and Görg (2004) find no effect in the electronics sector and Görg et al. (2008) only for exporting plants. Outsourcing of materials can have a positive (Görzig and Stephan, 2002) or insignificant impact Görg et al. (2008).

Our analysis differs from the studies above in so far that we look at how the closure of a vertically integrated plant (and not the increase in imports of intermediate inputs) affects the firm level employment. The literature on the effects of plant closures on firm level employment is rather restricted and as far as the author knows, this is the first analysis of the impact of vertically integrated plant closure on employment and productivity. Additionally, our data allows us to decompose the total employment effect into a direct and indirect effect. We can also infer how the closure will affect the firm level labour productivity.

Our main results are that we find a strong negative impact of fragmentation on employment, where the medium-run (3 – 5 years) impact is much larger for manufacturing than for tradable service firms. The first year after fragmentation employment decreases by 17% in manufacturing and 16% in the tradable service sector. Employment losses increase to 23% after five years in manufacturing, but reduce to 13% after 3 years in the tradable service sector. While we find a negative indirect employment effect for manufacturing firms in the medium-run, we find positive, increasing indirect effects in the service sector. The impact on productivity is large in manufacturing. There is an immediate productivity increase by 27%, which decreases to 15% after 5 years. There are no immediate productivity effects in the service sector. After three years we find an increase by 6%, but as regression analysis reveals, this value is not robust.

This chapter will be structured as follows: First, a summary of the literature about outsourcing and its effects on employment and productivity will be presented. We then describe how the data was prepared and which firms were allocated to a treatment or control group. The next section explains the empirical strategy employed and which dependent and independent variables were chosen. In section 6.5 we show our main results. This chapter finishes with a conclusion.

6.2. Literature

We look at the firm employment and productivity effects caused by an exiting vertically integrated plant, which we will call fragmentation. We focus on plant closures, because only the minority of exiting plants are sold.[185] As far as the author knows no theoretical or empirical paper exists to describe or follow this approach.[186]

Some papers exist using a specific example to describe the consequences of a plant closure for the region and for the workers. For example, Rowthorn and Ward (1979) conduct a cost-benefit analysis on the closing down of the steel making plant in Corby. They show that the closing down would not only affect workers working at the plant, but also auxiliary sectors in this region. Hinde (1994) looks at effects of the closing down the British Shipbuilding (BS) Yards on workers in Sunderland.

The literature most related is the international offshoring and outsourcing literature. The main similarity between those and this chapter is that a link between fragmentation and employment is set up. We expect to find a similar theoretical foundation and empirical framework. The main differences are that this chapter does not look at international linkages and the way fragmentation is measured. In general, fragmentation is measured by looking at how many goods a firm imports from abroad, where sometimes intermediate and final goods can be distinguished. In our model, fragmentation can only arise if a whole plant is closed. In general, total firm employment effects are considered, while we differentiate between direct and indirect effects.

The theoretical literature comes to ambiguous results about the effects of fragmentation on employment (Bottini et al., 2007). If foreign workers are substitutes for domestic

[185] Note that Harris and Moffat (2011) find, contrary to our findings, that brownfield plants are more likely to be in operation in manufacturing and service sectors. One reason could be that if firm A takes over another firm B, the plants will be regarded as brownfield plants of company B. However, we look at the case where a firm has an exiting plant, but continues to exist. In case of firm A, we would not regard this scenario as a plant exit.

[186] A more detailed literature review including studies at the economy, industry and plant level can be found in section 2.3 on page 57.

workers, offshoring can increase the domestic unemployment rate. A positive effect can arise from efficiency gains, which then reduces unemployment rates.

Several studies about the effects of fragmentation at the firm level have been published recently. Biscourp and Kramarz (2007) use French manufacturing data for 1986 – 1992 and compare the employment growth rates of firms which started to off-shore abroad and firms which did not. They find evidence that offshoring firms suffered heavier jobs losses than non-offshoring firms. Hijzen et al. (2011) use a similar approach but come to different conclusions. The authors focus on the effect of offshoring of producer *services* on the labour employed in UK firms of the manufacturing *and* financial and business services sector for the period 1996 – 2004. Firms which start offshoring are experiencing an even higher employment growth than firms which have never imported services. Ando and Kimura (2007) conduct a similar analysis for Japanese firms for the Period 1998 – 2003. They found evidence that offshoring does have a significant positive effect on a company's decision not to reduce employment. If a firm is increasing the amount of offshoring abroad it leads to growth rates of employment of 3 – 8 percentage points higher than of other manufacturing firms. This cannot be observed for non-manufacturing firms.

Hijzen et al. (2009) explain the positive employment effect by arguing that vertical FDI leads to efficiency gains to withstand competitive pressures and Ando and Kimura (2007) with that, at least for manufacturing, domestic and foreign production processes are complements rather than substitutes. Another reason could be that the increased demand for outsourced inputs coincides with a positive (unobserved) demand shock, which would question the causality of the results above.

Besides using a rather descriptive approach, a quasi-experimental technique, like Difference-in-Differences (DiD) (Hijzen et al., 2010) and propensity score matching (Hijzen et al., 2009, 2011) can be used for analysis. Hijzen et al. (2010) look at how mass lay-offs or plant closures affect the earnings of displaced workers. Even though this paper does not directly touch the question of the firm employment effects after the closure of a plant, the empirical strategy used in this paper will be one of the main foundations of this chapter and will be discussed in section 6.4. Besides implementing a DiD estimator they also use propensity score techniques. Hijzen et al. (2009) follow this approach and analyse the effects of internationalisation of a firm on the performance of the firm for the period 1984 – 2002. The authors differentiate between manufacturing and service sector and horizontal and vertical Foreign Direct Investment (FDI). They find that FDI of the service sector and horizontal FDI of manufacturing firms into high income countries and industries, where the firm has a comparative advantage in, have a significant positive impact on domestic employment in comparison to firms which did not internationalise. Even for vertical FDI of manufacturing firms no evidence for job losses for the parent firms was found.

The theory about productivity is quite clear. Fragmentation and focusing on the core activities of a firm should increase productivity. The empirical evidence is not as straight forward (Olsen, 2006). Görzig and Stephan (2002) show that return per employee of German manufacturing firms is positively affected by material outsourcing, subcontracting and service outsourcing in the long-run. In the short-run, service outsourcing has a negative impact. Girma and Görg (2004) examine the effect of an increase in the outsourcing intensity on labour productivity and TFP for UK firms of the chemical, the electronics and the engineering sector. Only in the chemical and the engineering sector a positive effect of outsourcing can be found. Hijzen et al. (2009) study the productivity effects of French firms through off-shoring. For the manufacturing sector they find large but imprecise positive productivity gains through vertical FDI, but no productivity gains through horizontal FDI. Offshoring does not have a positive productivity effect for the service sector. Görg et al. (2008) focus on Irish plant level data. They find that only for exporting plants, independent of being foreign owned or not, outsourcing of services has a positive impact on TFP. No significant impact is found of outsourcing of material inputs. Recently anecdotal evidence can be found about firms revaluating their outsourcing decisions (for example BBC, 2009 and The Telegraph, 2010). Outsourcing may reduce labour costs, but quality standards cannot be met anymore, leading to reduced sales. For example, relocating UK contact centres to Mumbai reduces the labour costs by 90 percent. The cost of customer lost was £12m a year, therefore the expected increase in profitability did not happen (UKTI, 2010).

To conclude, we find mixed empirical evidence on the effects of fragmentation on employment and productivity.

6.3. Data, Treatment and Control Groups

The main database used is the BSD for the period 1998 – 2008, which is described in detail in chapter 3. The NSPD is used for classifying the postcodes into local authorities, the BERD for industry in-house R&D intensities and the ASHE for the degree of unionisation. Again the manufacturing and the tradable service sector are considered. Before we can start with the analysis the data will be modified. Our "treatment" is fragmentation, the sourcing of former internally produced intermediate inputs from the market. This is measured by a firm selling or closing down one of its vertically integrated local units in any year between 1998 – 2007.[187] [188] Because those events are quite rare, we follow the data manipulation of Hijzen et al. (2009) and Hijzen et al. (2010). First every year is considered separately. For example, firms which close a plant in 2000 will be in the treatment group of year 2000, and firms which did not close a plant will be part of the control group 2000. We follow this approach for every year. Then a relative time measure t^* will be introduced, which is 0 when the treatment happens, -1 one year before and 1 one year after the treatment, etc. We will end up with $-9 \leq t^* \leq 10$. We will then stack

[187] We define the year of closure as the year when the local unit appeared the last time in the dataset. The reason is that the BSD is a record of firms in March. Therefore if a plant disappears for example in the BSD in 2001, it means that it exited between March 2000 and March 2001.

[188] We discuss the treatment group in the next section.

up all the cohorts, so that firms of the control group can appear more than once.[189] This modification will create a correlation in the error structure, therefore clustered standard errors have to be used. The clusters used are the original firm identifiers. So if a firm appears several times the cluster includes several observations from the same firm.

We create different treatment and control groups depending on different selection rules. This has been conducted to show that the results are robust. All selection rules have in common that in the pre-treatment period no plant has exited or entered a firm. The differences arise after the treatment appeared. Our main sample will only consider firms which, after the treatment happened, do not close or open any other local unit. The second selection rule is far less restrictive. After the treatment all firms, regardless if they open or close any plant, will be kept. We will discuss the treatment and the control groups in far more detail now.

Treatment group

The treatment group consists of those firms which are shutting down or selling *one* vertically integrated plant within in the observation period. More specifically, forward vertically integrated plants matter. If a forward vertically integrated plant exits the firm, then those intermediate inputs have to be sourced from the market. Table 6.1 illustrates what kind of event is of interest. It shows a simplified version of the BSD with made-up data, sorted by firms and year. Scenario I shows the straight forward case. Firm A owns two local units of different industries, *1* and *2*, where both plants provide intermediate inputs for the other firm. In 2001 local unit *2* is sold, therefore all intermediate inputs have to be sourced externally. The treatment dummy for the firm will be one. Scenario II shows firm B, which owns only horizontally linked local units. Even though local

[189] Hijzen et al. (2010) explain that a treated firm can also appear more often in the treatment group if a treatment happens more than once over time. In contrast to that I have included only firms which experience a treatment once. Additionally, firms of the treatment group do not appear in the control group later.

unit *4* exits, it will not change the treatment dummy. Scenario III is trickier. One assumption has been so far that, if a firm has a company producing intermediate inputs, it was sufficient to satisfy the firm's internal demand for this intermediary.[190] If a local unit exits, but there is still another local unit of the same industry, then the plants left are sufficient to produce the required intermediate inputs or, to put it differently, the fragmentation motive will only come into existence if no plants of the same industry within a firm exist anymore.[191] On the other hand, if an intermediate input supplying plant is closing, then the firm has to source them from the market and we still can refer to it as fragmentation. For example, enterprise C has three local units, where *5* and *6* are of the same and *7* is of another industry. In 2000 plant *6* shuts down. We will allocate that firm to the treatment group, even though it has another plant left in the same industry, since it seems reasonable to assume that such an event is a type of fragmentation because it represents a shift from internal provision of intermediates to external supply.

Firms will be only part of the treatment group if they close one vertically integrated plant at $t^* = 0$. If they close more than one vertically integrated plant or any other horizontally linked plant, then they will not be considered for the treatment group. The restricted treatment group will only include firms which, after the treatment happened, do no close any other plant. The less restrictive treatment group contains also firms which close and open other local units in the post-treatment period. The implication is that, because of fragmentation, a firm may specialise or changes its organisational structure further and set-up or close down another local unit. For example, a firm fragments it production and, because of specialisation, it open another plant in its core activity. It is expected that this can have a positive (if new plants appear) or negative (if additional plants are exiting) effects on total employment.

Regardless of whether or not firms are kept in the post-treatment period which keep their

[190]See page 115 for a description of required assumptions for the vertical integration measure.

[191]For example, to save costs it might be possible to concentrate production in one location, so this plant closure is not related to fragmentation.

local unit structure or close and open other local units, we only consider fragmentation for firms which close one plant only at $t^* = 0$.

I.	**Ent. Ref.**	**LU Ref.**	**SIC**	**vif$_{\mathbf{lu}}$**	**vif$_{\mathbf{firm}}$**	**frag**
1999	A	1	15	1	1	1
1999	A	2	20	1	1	1
2000	A	1	15	0	0	1
2000	A	—	—	—	—	—
II.						
1999	B	3	15	0	0	0
1999	B	4	15	0	0	0
2000	B	3	15	0	0	0
2000	B	—	—	—	—	—
III.						
1999	C	5	15	1	1	1
1999	C	6	15	1	1	1
1999	C	7	20	1	1	1
2000	C	5	15	1	1	1
2000	C	—	—	—	—	—
2000	C	7	20	1	1	0

Table 6.1: Derivation of the treatment dummy

Control group

The choice of the control group is crucial for a DiD analysis. *Firstly*, the control group should contain those firms which "might" have closed down a vertically integrated plant, but which did not. We have excluded single plant firms, because they cannot fragment according to our definition. As mentioned on page 169, they are significantly different to multi-plant firms.

Secondly, the characteristics of the treatment and the control groups can be very different from each other. However, a key assumption is that the trends of the control and treatment group are the same in the absence of treatment, for example, the control group is not growing faster or slower. Another assumption is that the control groups are not affected by the treatment. This can happen, for example, if there are spillovers. Besley and Case (2000) give an example about how the choice of the control group can affect the results.[192] [193] Results are very sensitive to which control group (counterfactuals) have been chosen (Hijzen et al., 2010). To have firms following rather similar trends we will keep only those firms which are not significantly larger according to turnover and employment and did not close and open any plants before $t^* = 0$. We use only manufacturing firms as a control for the treated manufacturing firms, and for tradable service firms only firms of the tradable service sector. Based on this our control group consists of firms which are vertically integrated. This fits to our first requirement that we only keep firms which could potentially close a vertically integrated plant. I will also create another comparison group which includes also non-vertically integrated multi-plant firms. This group is only kept to see how the average firm which did not fragment at $t^* = 0$ behaved in comparison to the treatment group. Note that this group is not suitable as control group because it violates the assumption that only firms can be in the control group which could potentially fragment.

6.4. Empirical Strategy

Common problems in empirical research are caused by the correlation between the error term and the covariates. We already discussed the omitted variable bias and endogeneity problems in the last chapter and how they can be mitigated in certain circumstances by using fixed effects estimation methods. For example, firm fixed effects can take care of unobserved or omitted firm specific factors, which are time invariant. Time fixed effects can take care of factors, which are time variant, but are the same for all firms.

[192] Besley and Case (2000) show how an increase in workers' compensation benefits affects average earnings. The treatment groups are US states which experienced an increase in benefits, and control groups are the other states experiencing no change. Some control states seem to be inappropriate, because of significantly differing unemployment growth rates, which may affect average earnings differently.

[193] An example of a nearly identical treatment and control is provided by Ashenfelter and Krueger (1994) mentioned in Cameron and Trivedi (2009). They are using data of twins to find the effect of schooling and wages. This should take care of the differences in unobservable ability.

Still two problems remain. Firstly, if unobserved factors, or factors, for which no data is available, are time variant and different for every firm, then fixed effect estimations will not solve the problem and the biased results will remain. We will illustrate it with equation 6.4.

$$Employment_{it} = \beta_0 + \beta_1 frag_i + \beta_2 X_{it} + a_{it} + \varepsilon_{it} \tag{6.4}$$

where $frag_i$ indicates if firms are fragmenting or not, X contains other firm related covariates and the unobserved effect is captured by a_{it}. If a_i was time invariant, by taking a within-group estimator, a_i would disappear. Because a_{it} is changing over time, this bias will still remain. a_{it} is any unobserved firm specific shock to labour demand. If that shock is correlated with $frag_i$, results will be biased, and it seems likely that they are correlated. For example, a firm loses a big customer and as a result needs to lay-off workers. The firm may choose then to shut down its least efficient plant. If this firm had not shut down that plant, maybe it would have done even worse. In other words, the demand shock caused both the employment loss and the decision to sell-off the plant.

Another problem is selection bias which can create misleading results. To test the effects of fragmentation we could compare the number of people employed in firms which closed a vertically integrated plant and firms which did not close a plant. Following the notation of Angrist and Pischke (2009) the observed difference in average firm employment is on the left hand side of equation 6.5.

$$\begin{aligned}\underbrace{E[emp_i|frag_i = 1] - E[emp_i|frag_i = 0]}_{\text{Observed difference in av. employment}} = \underbrace{E[emp_{1i}|frag_i = 1] - E[emp_{0i}|frag_i = 1]}_{\text{Av. treatment effect on the treated}} + \\ + \underbrace{E[emp_{0i}|frag_i = 1] - E[emp_{0i}|frag_i = 0]}_{\text{Selection Bias}}\end{aligned} \tag{6.5}$$

where emp_{0i} captures the employment of a firm which did not fragment and emp_{1i} the employment if a firm fragmented. Those two expressions do not imply if a firm actually fragments or not. The first term on the right hand side shows the average treatment effect on employment. This is what we want to measure. What is the difference between the employment level of a fragmented firm and the employment level of a fragmented firm, if it had not fragmented? We cannot observe $E[emp_{0i}|frag_i = 1]$. What problems it can cause is illustrated by the second term in equation 6.5. This term captures the selection bias and illustrates differences between treated and non-treated firms, even if the actual treatment would not have happened. This selection bias can outweigh the actual treatment effect. Even if a firm closes a vertically integrated plant and reduces the number of people employed non-treated firm can be genuinely smaller, and therefore the average employment effect would appear to be positive. If the fragmenting and the non-fragmenting firms are similar, then the selection bias would difference itself away. Unfortunately the comparison group is normally different. A numerical example shall illustrate this case:

We can observe that fragmenting firms have on average 100 employees, non-fragmenting firms 50. The observed difference in average employment would be 50. We cannot conclude that fragmentation leads to firms being on average bigger by 50 employees. The right hand side of the equation will show why. If the firm had not fragmented, it would have had 120 employees, therefore the treatment effect we have been looking for is minus 20 employees. The selection bias in our example is 70 $(120 - 50)$, resulting in misleading results.

A method to solve the second problem is by using a Difference-in-Differences estimator (see Wooldridge, 2002, Cameron and Trivedi, 2009, and Angrist and Pischke, 2009). The basic set-up consists of at least two time periods, a pre- and post-treatment period and two different groups, one group receiving a treatment and another group which did not. To calculate the net effect of the treatment, one could first run a regression on the second time period only. The coefficient of the treatment dummy would then indicate how much the treatment affected the treated group in comparison to the non-treated group. In the example above, it would be the difference in employment of fragmenting and non-fragmenting illustrated in equation 6.5, which was 50. It could be the case that fragmenting firms are already bigger than non-fragmenting firms. By running a similar regression for the first period the coefficient of the treatment dummy gives information about how much the two groups were different even before there was a treatment. By differencing now the size differences of both periods a more reliable statement can be made about the effects of the treatment. Using the example from above again, if the fragmented firms have already been bigger in the first periods by 70 employees, then we would get the treatment effect of -20 $(50-70)$.

We present a basic DiD model in equation 6.6.

$$emp_i = \beta_0 + \beta_1 frag_i + \beta_2 T_2 + \beta_3 T_2 \times frag_i + \beta_4 X_i + \varepsilon_i \tag{6.6}$$

where T_2 is a time dummy for the post-treatment era, $frag_i$ is a fragmentation dummy, and X_i captures all other factors. The coefficient of interest is β_3, the treatment effect. We want to analyse how the treatment affects the employment of the firm over more than one period. Equation 6.6 can be easily modified to take account of this:

$$emp_{it} = \beta_0 + \beta_1 frag_i + \sum_{k=t^*_{min}}^{t^*_{max}} \beta_2^k T_{it}^k + \sum_{k=t^*_{min}}^{t^*_{max}} \beta_3^k T_{it}^k \times frag_i + \beta_5 X + \varepsilon_{it} \tag{6.7}$$

β_3 captures the treatment effect, which can be followed now over several observation periods.[194] Covariates can be added to capture more time variant firm specific factors.

[194] Autor (2003) conducts a similar model. His paper deals with the employment changes of temporary help services (THS) in the US through law changes. To observe dynamic effects, he estimated to following model:

$$y_{ist} = \gamma_1 d_s + \gamma_2 d_t + \sum_{\tau=0}^{m} \delta_{-\tau} D_{s,t-\tau} + \sum_{\tau=1}^{q} \delta_{+\tau} D_{s,t+\tau} + X'_{ist}\beta + \varepsilon_{ist}$$

where $D_{s,t\pm\tau}$ represent the interaction term of the time and state dummies. This model enables to see the dynamic changes over time. The first sum term captures all periods before the treatment

We fix the value of the covariates to two periods before the treatment. We will use this estimation method for our balanced sample.

A generalisation of DiD is possible if instead of group fixed effects $frag_i$ individual firm fixed effects are considered by using a within-group estimator. If a balanced panel is used, both DiD and fixed effects estimators will lead to identical results. However for unbalanced panels estimates will be different. Hijzen et al. (2010) suggest using FE estimates for unbalanced panels.

In general DiD can take care of unobserved heterogeneity if the shocks are affecting the treatment and control group similarly. Also differences between firms before the treatment can be controlled for. If $E(a_i|frag_i) = 0$, we are able to interpret our results in a causal way. However, we cannot be sure that we capture the causal link between fragmentation and employment. On the one hand, the problem of unobserved time varying factors remains leading to biased results. On the other hand, the sample selection bias still remains. We cannot be confident about that our control groups are capturing the appropriate counterfactuals. In the most extreme case $E(emp_{0i}|frag_i = 1)$ can be zero. This means that the firm would have gone bankrupt without fragmenting, and therefore we are underestimating the true impact of fragmentation on firm level employment.

Concluding, DiD requires the strong assumption that the outcome effect for fragmenting firms would have been the same in the post-treatment period, if they had not been fragmenting, as for non-fragmenting firms. This might be unlikely because of self-selection. For example, fragmenting firms would have reduced the number of people employed, relatively to non-fragmenting firms, anyways, otherwise they might have to shut down the whole enterprise.

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and the second sum term all the after treatment periods. More precisely Autor (2003) creates two variables for capturing two pre-treatment periods, four variables to capture the post-treatment period $\tau = 0, 1, 2, 3$ and a seventh variable to identify all post-treatment periods for $\tau > 3$.

6.4.1. Dependent variables

Three dependent variables will be used. First, the total amount of labour employed within a firm to capture the total employment effects. Second, the employment of the firm net of the employment of the exiting plant to capture indirect employment effects and finally total sales to be able to find the effect of fragmentation on labour productivity. We are going to compare the employment and turnover figures after treatment with the employment and turnover figures at $t^* = -2$. It can be the case that in the year of the treatment the firm is already anticipating the closure of the plant by moving jobs to other plants or reducing already the workforce.[195]

6.4.2. Independent variables

The choice of independent variables is crucial, so we can control for specific differences between the control and treatment groups. We will use covariates from the pre-fragmentation periods only to see how the pre-treatment factors are affecting post-treatment turnover and employment.

Firm related factors

Biscourp and Kramarz (2007) and Hijzen et al. (2011) use the change of sales to indicate technological and firm size changes, which are unrelated to fragmentation. For example, a temporary boom period might lead to higher employment within a firm, but is unrelated to fragmentation. Turnover figures are available for most firms in the BSD. We use the sales change one period before fragmentation instead of two periods before, like for other covariates. The reason is that we would lose many observations if we used the change of sales for period $t^* = -2$.

[195] This anticipation is also called "Ashenfelter dip" after Ashenfelter (1978). Note that anticipation is not the only reason for the "Ashenfelter dip" to appear. It may be an indication of an unobserved shock which initially causes a change in the dependent variable and then the entry into treatment.

Total employment, age and foreign ownership will also be used. The larger the firm is, the likelier it is to decrease a larger number of employees. The effect of the age variable can be ambiguous. Foreign ownership is expected to amplify the employment reduction, because the further away the headquarters are the less do managers care about the regional consequences (Landier et al., 2009). It can also be the case that foreign-owned firms are more likely to outsource or offshore.

Industry factors

Unionisation is an important factor for employment changes of firms. If a firm is in a highly unionised sector it is assumed that the employment fluctuations will be significantly smaller than in unprotected industries. Especially the short-run effects are assumed to differ significantly. Ando and Kimura (2007) also add an independent variable for in-house R&D of an industry. Unfortunately they do not mention any underlying theory behind this variable.

6.5. Empirical Results

6.5.1. Stylized facts

How often are local units closed? Table 6.2 gives the answer. We consider only firms which have been a multi-plant firm at least once and exiting local units if the parent firm continues to exist. In the second column *cont* we can see the number of local units which remained part of a firm and in the *ex tot* column the total number of local units which exited a firm.[196] Columns 4 (*ex ho*) and 5(*ex vi*) contain a distinction between the number of horizontally linked and exiting vertically integrated local units. More vertically integrated local units have been closed in manufacturing and more horizontal

[196]Exiting is identified by the disappearance of a local unit id number in the data. Therefore changes in id numbers might cause spurious closures. As shown on page 72, the reference numbers are rather reliable in the BSD.

local units in the tradable service sector. Only four percent of exiting local units have been sold in manufacturing and three percent in the tradable service sector.[197] In our sample fragmentation is mainly driven by plant closures.

On the right hand side of the table we show how many firms are closing at least one (*firm ex*) and in the last column (*firm cont*) how many firms did not close any vertically integrated plant. The number of firms closing a plant is five times larger in the manufacturing sector than in the tradable service sector. In general the majority of firms does not fragment.[198] Not all firms which close a vertically integrated local unit will be considered for the treatment group. In the next section we are going to discuss in detail the treatment and control groups.

6.5.2. Sample

We create a balanced and an unbalanced data set. The unbalanced data set has the advantage of having a bigger sample size, but suffers from an under-represented sample in later post-treatment years. Results can be biased if the cause of missing observations is endogenous (Dougherty, 2007). In table 6.3 we show the size of the used samples. On the left side of the table the restricted sample and on the right hand side the unrestricted sample are presented. This is further divided into a balanced and unbalanced sample and those are then separated into a control and a treatment group.

We focus our analysis on the balanced samples and use the unbalanced samples for robustness checks. In manufacturing the number of firms in the balanced treatment sample is 165 and in the tradable service sector it is 64. The observation period chosen is from $t^* = -2$ to $t^* = 5$. That means that fragmentation must have happened between

[197] Because of confidentiality requirements we are not allowed to show in detail how many local units have been sold or closed down.

[198] In the appendix on pages 303*f* in tables D.1 – D.2 we provide some more statistics, showing in which regions and industries the majority of local units has been closed.

Manufacturing						
	Local units				*Firms*	
year	**cont**	**ex tot**	**ex ho**	**ex vi**	**firm ex**	**firm cont**
1998	29,161	760	330	430	235	11,529
1999	27,097	2,151	1,035	1,116	656	10,891
2000	25,941	1,860	804	1,056	466	10,778
2001	24,532	1,846	853	993	524	10,365
2002	23,890	1,667	843	824	478	10,002
2003	21,709	1,738	954	784	442	9,400
2004	20,781	1,739	818	921	501	8,803
2005	19,498	1,705	847	858	585	8,170
2006	19,021	1,286	607	679	415	8,008
2007	18,519	1,267	621	646	418	7,630
Tradable Services						
1998	30,915	448	362	86	61	11,792
1999	28,276	3,334	2,400	934	274	11,888
2000	27,972	3,036	1,470	1,566	178	12,035
2001	27,125	3,331	1,631	1,700	188	11,932
2002	26,294	3,020	1,552	1,468	197	11,470
2003	25,452	2,348	1,678	670	175	10,981
2004	24,957	2,424	1,614	810	239	10,308
2005	23,131	2,486	1,664	822	266	9,409
2006	23,275	1,815	1,097	718	191	9,121
2007	23,147	1,882	1,119	763	217	8,733

Table 6.2: Number of closing local units

Manufacturing								
	Restricted Sample				**Unrestr. Sample**			
	Balanced		Unbalanced		Balanced		Unbalanced	
t^*	Control	Treat.	Control	Treat.	Control	Treat.	Control	Treat.
-3			5,211	367			9,493	549
-2	2,591	165	6,284	423	5,840	310	11,668	680
-1	2,591	165	6,284	423	5,840	310	11,668	680
0	2,591	165	6,284	423	5,840	310	11,668	680
1	2,591	165	6,284	423	5,840	310	11,668	680
2	2,591	165	5,211	366	5,840	310	10,117	595
3	2,591	165	4,245	319	5,840	310	8,601	525
4	2,591	165	3,382	221	5,840	310	7,136	385
5	2,591	165	2,591	165	5,840	310	5,691	296
6			1,871	105			4,236	205
Tradable Services								
-3			2,160	82			4,099	153
-2	1,737	64	2,637	94	3,897	134	5,127	174
-1	1,737	64	2,637	94	3,897	134	5,127	174
0	1,737	64	2,637	94	3,897	134	5,127	174
1	1,737	64	2,637	94	3,897	134	5,127	174
2	1,737	64	2,160	81	3,897	134	4,411	147
3	1,737	64	1,737	64	3,897	134	3,722	117
4			1,376	40			3,065	77
5			1,051	24			2,419	50
6			755	16			1,793	35

Table 6.3: Sizes of different treatment and control group samples

2000 and 2003.[199] This seems to restrictive for the service sector, because we would be left with only 24 firms. Therefore the post-treatment period range was reduced to $t^* = 3$. Firms which fragmented between 2000 and 2005 will be included. We will have a treatment sample of 64 firms. We relax this assumption for the unbalanced sample. The restriction left is that we only keep firms which have appeared in period $t^* = -2$ and $t^* = 1$. Because at the beginning and the end of the t^*-period only few firms appear we focus on the period $-3 \leq t^* \leq 6$.

6.5.3. Descriptive analysis

Before we can conduct the DiD analysis, we have to compare the characteristics of the control and the treatment group with each other. It is important that the development

[199]If the fragmentation happened before 2000, then we could not observe $t^* = -2$ and if it is after 2003 we could not follow the company over the next five years after fragmentation.

of the characteristics of both groups is not too different from each other. The following graphs in figure 6.2 will compare the development of the dependent variables before and after the treatment.

In the top part of the figure we can see the differences of the treatment and control groups in employment, net employment and real firm labour productivity for the manufacturing and in the bottom for the tradable service sector. The timing of the treatment is illustrated by the vertical line. First, the performance of the control groups looks quite similar in terms of trends, but are just at a different level. We can observe a strong effect of fragmentation on the *total employment* in manufacturing. Two periods after the treatment the performance seems to be similar between the treatment and the control groups. Note that we also add a group which includes also non-vertically integrated local units. Keeping non-vertically integrated local units does not change the performance of non-treated firms. Only the level of employment and productivity seems to differ.

For the tradable service sector we observe a decrease of total employment in period one after the treatment, but then employment stabilises and increases again slightly. A small and positive *indirect effect* can be observed in manufacturing a period after the treatment, which turns into significantly negative effect after 5 periods. In the service sector the employment in all other plants is increasing slightly. Finally the development of real labour productivity looks more erratic then the employment figures, which can be caused by more fluctuating sales figures. We can still observe an increase in labour productivity after the treatment, which was highest immediately after the treatment. The picture in the service sector is less clear. Three years after the firm fragmented, we can observe a higher productivity, but a period before we would have observed a lower productivity.

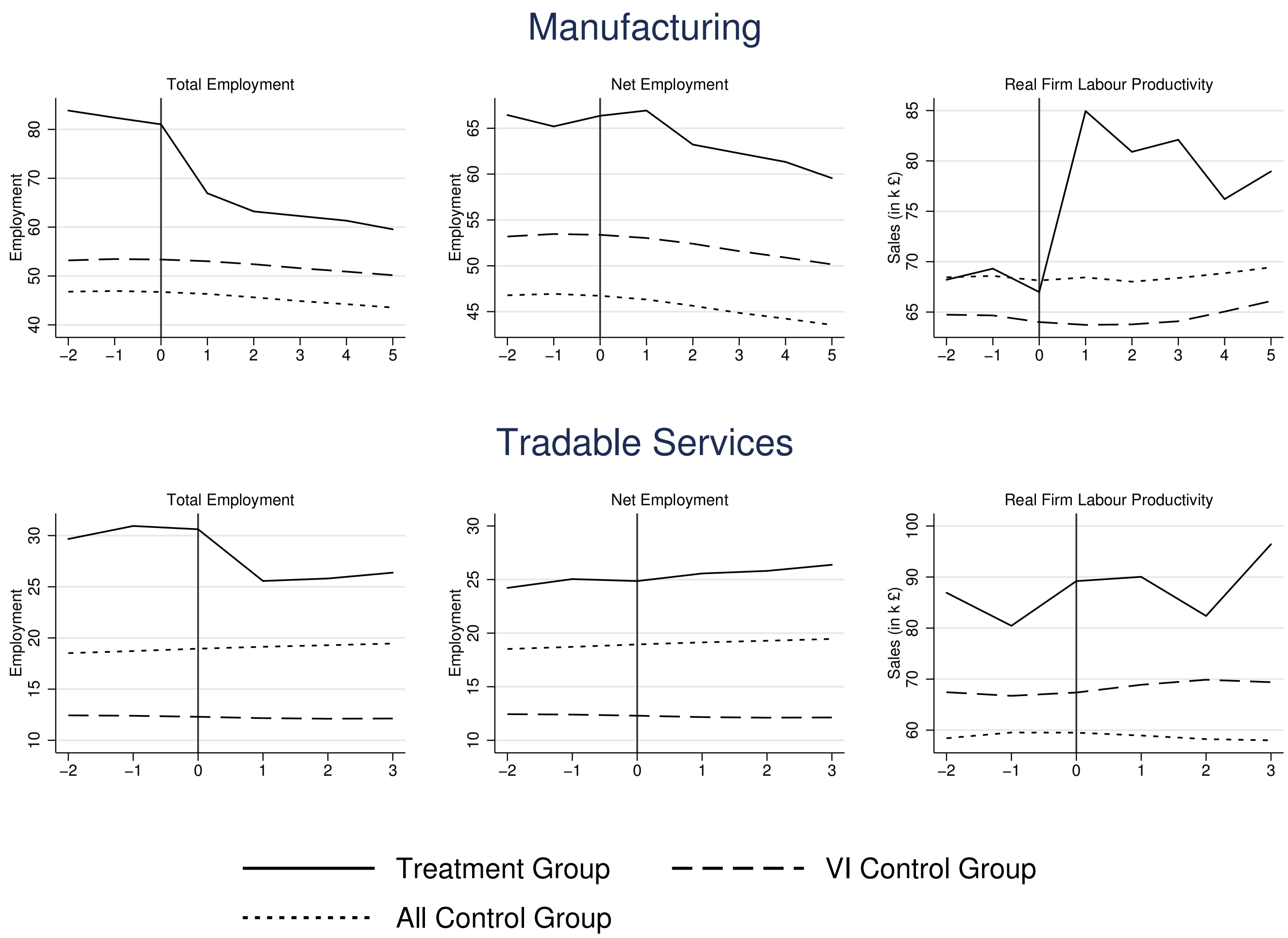

Figure 6.2: Development of dependent variables before and after treatment for control and treatment groups

We will discuss the characteristics of each group in more detail now by using tables 6.4 – 6.5. We have already seen that employment and turnover is larger in the treatment group than in the control group. In manufacturing the average firm level labour productivity is about the same for the treatment and the control group in the pre-treatment period. The share of foreign owned plants, the degree of unionisation, the number of plants and the market concentration are similar in both groups. More firms in the control group are in R&D intensive industries. We can already conduct a first DiD analysis.

In period $t^* = 1$ employment drops sharply. The total employment effect is -14.11 workers. We can calculate a direct and indirect effect. The indirect effect in $t^* = 1$ is with $+0.57$ $(66.93 - 66.36)$ rather small and turns to -6.8 in $t^* = 5$. The direct effect is -14.68 $(81.04 - 66.36)$. The employment change in the vertically integrated control group is -0.35 in $t^* = 1$ and -3.22 in $t^* = 5$. The result of the DiD is that the treatment causes treated firms to experience a decrease in total employment by -13.76 (17%) in $t^* = 1$ and -18.26 (23%) in $t^* = 5$ in comparison to the control group. The indirect effects let total employment gradually decrease further over time.

For labour productivity we can only calculate a direct effect. Real labour productivity increased in $t^* = 1$ by £17.96k and in $t^* = 5$ it is still £11.97k higher than in $t^* = 0$. In the vertically integrated control group we can only find a small change of -£0.28k in $t^* = 1$ and £2.08k in $t^* = 5$. DiD shows that labour productivity for the treatment group increased by £18.24k (27%) in $t^* = 1$ and £9.89k (15%) in $t^* = 5$ in comparison to the treatment group. We find a large positive effect of fragmentation on labour productivity, even though the effect gets smaller over time. While labour productivity was about the same in the treatment and in the control group, it is much higher now in the treatment group.

					Manufacturing					
t^*	Obs.	Employment	Net Emp.	R. Turn.	R. Firm Prod.	No. of Plants	Foreign	Concent.	Unionisation	Ih R&D
Treatment Group										
-2	165	83.86	66.44	6,879	68.21	2.26	0.18	0.21	0.46	0.19
-1	165	82.41	65.20	6,764	69.31	2.26	0.19	0.22	0.44	0.20
0	165	81.04	66.36	6,331	66.99	2.26	0.11	0.22	0.43	0.25
1	165	66.93	66.93	6,050	84.95	1.26	0.09	0.25	0.42	0.26
2	165	63.22	63.22	5,954	80.90	1.26	0.09	0.25	0.40	0.28
3	165	62.27	62.27	5,612	82.10	1.26	0.10	0.28	0.39	0.25
4	165	61.33	61.33	5,530	76.21	1.26	0.09	0.25	0.38	0.33
5	165	59.56	59.56	5,636	78.96	1.26	0.12	0.26	0.38	0.37
VI Control Group										
-2	2,591	53.20	53.20	4,829	64.74	2.23	0.19	0.22	0.45	0.29
-1	2,591	53.47	53.47	4,872	64.67	2.23	0.19	0.22	0.44	0.34
0	2,591	53.38	53.38	4,870	64.01	2.23	0.12	0.23	0.42	0.40
1	2,591	53.03	53.03	4,871	63.73	2.23	0.09	0.23	0.41	0.47
2	2,591	52.41	52.41	4,883	63.78	2.23	0.07	0.23	0.39	0.52
3	2,591	51.60	51.60	4,888	64.09	2.23	0.06	0.24	0.37	0.54
4	2,591	50.90	50.90	4,961	65.05	2.23	0.06	0.25	0.35	0.56
5	2,591	50.16	50.16	5,040	66.09	2.23	0.06	0.26	0.33	0.55
ALL Comparison Group										
-2	5,073	46.79	46.79	4,390	68.45	2.16	0.18	0.21	0.45	0.25
-1	5,073	46.94	46.94	4,416	68.59	2.16	0.18	0.22	0.44	0.31
0	5,073	46.73	46.73	4,364	68.14	2.16	0.11	0.23	0.42	0.39
1	5,073	46.33	46.33	4,319	68.44	2.16	0.08	0.23	0.41	0.46
2	5,073	45.64	45.64	4,286	68.02	2.16	0.06	0.23	0.39	0.52
3	5,073	44.87	44.87	4,276	68.38	2.16	0.05	0.24	0.37	0.56
4	5,073	44.24	44.24	4,296	68.86	2.16	0.06	0.25	0.35	0.57
5	5,073	43.56	43.56	4,343	69.44	2.16	0.06	0.26	0.34	0.56

Table 6.4: Descriptive statistics for control and treatment groups in the manufacturing sector

We will discuss now the tradable service sector. The size of firms with regards to employment and turnover in the treatment group is much larger than in the control group. The average firm of the treatment group is more productive than in the control group. Total employment is rather constant and real turnover is decreasing in the control group, the average employment size and the real turnover are increasing. The employment figures are rather fluctuating in the treatment group. This is caused by one large firm with volatile employment figures. The regression results are not affected by this large firm, but, because we are using levels for the descriptive part, we will exclude that outlier. The descriptive statistics with the outlier can be found in the appendix on page 305. The total employment effect is -5.05 $(25.57 - 30.62)$ in $t^* = 1$ and -4.24 in $t^* = 3$. This is again driven by the direct effect -5.76 $(30.62 - 24.86)$ and slightly mitigated by the indirect effect with the value 0.71 $(25.57 - 24.86)$ in $t^* = 1$ and 1.52 in $t^* = 3$. Employment in the control group changes by only -0.13 in $t^* = 1$ and -0.17 in $t^* = 3$. The basic DiD analysis therefore reveals that total employment decreased by 4.92 in $t^* = 1$ (16%) and was reduced by 4.07 (13%) in $t^* = 3$

The immediate labour productivity effect is with £0.84k rather small in $t^* = 1$ but increases to £7.22k in $t^* = 3$ in the treatment group. In the control group the differences are £1.52k in $t^* = 1$ and £2.03k in $t^* = 3$. DiD shows that labour productivity decreases slightly by -£0.68k (-0.8%) in $t^* = 1$ but increases to £5.19k (5.8%) in $t^* = 3$. Contrary to the manufacturing sector we cannot observe an immediate productivity effect, but 3 years after the treatment a positive productivity effect appears. This value is still not very robust, because of a rather erratic behaviour of the labour productivity value. However, it seems that the productivity effect is much smaller in the service than in the manufacturing sector.

So far we just looked at the raw employment and turnover changes. We did not control for other factors, and cannot say anything about significance of those results. Therefore we will conduct a DiD analysis in the next section.

					Tradable Services					
t^*	Obs.	Employment	Net Emp.	R. Turn.	R. Firm Prod.	No. of Plants	Foreign	Concent.	Unionisation	Ih R&D
Treatment Group										
-2	63	29.67	24.22	2,811	86.92	2.32	0.12	0.07	0.25	5.66
-1	63	30.94	25.05	2,947	80.45	2.32	0.09	0.06	0.24	5.76
0	63	30.62	24.86	2,693	89.20	2.32	0.06	0.06	0.20	5.78
1	63	25.57	25.57	2,579	90.04	1.32	0.07	0.07	0.19	4.25
2	63	25.81	25.81	2,559	82.38	1.32	0.06	0.07	0.17	6.37
3	63	26.38	26.38	2,684	96.42	1.32	0.06	0.07	0.16	0.56
VI Control Group										
-2	1,737	12.44	12.44	840	67.43	2.16	0.08	0.10	0.29	1.45
-1	1,737	12.40	12.40	840	66.73	2.16	0.07	0.10	0.28	2.56
0	1,737	12.30	12.30	833	67.37	2.16	0.05	0.10	0.25	3.97
1	1,737	12.17	12.17	824	68.89	2.16	0.05	0.10	0.22	5.21
2	1,737	12.11	12.11	814	69.88	2.16	0.04	0.10	0.21	6.74
3	1,737	12.13	12.13	822	69.40	2.16	0.04	0.10	0.19	7.56
ALL Comparison Group										
-2	10,181	18.52	18.52	911	58.42	2.18	0.04	0.06	0.25	0.64
-1	10,181	18.72	18.72	938	59.54	2.18	0.03	0.06	0.23	1.07
0	10,181	18.95	18.95	956	59.51	2.18	0.02	0.06	0.21	1.65
1	10,181	19.14	19.14	968	58.95	2.18	0.02	0.06	0.19	2.12
2	10,181	19.29	19.29	970	58.25	2.18	0.01	0.05	0.17	2.73
3	10,181	19.46	19.46	981	58.01	2.18	0.01	0.06	0.15	3.09

Table 6.5: Descriptive statistics for control and treatment groups in the tradable service sector

6.5.4. Regression results

We provide three tables for each sector. In all tables we present the results for the balanced sample. In the first two coefficients columns we have the restricted and in the third and fourth column the unrestricted sample. In column one and three we use the vertical integration control group and in column two and four the comparison group containing also not vertically integrated Firms. The description of the results is focused on the former control group if not stated otherwise. In tables 6.6 and 6.9 the dependent variable is log employment, in tables 6.7 and 6.10 log employment without employment of exiting plant (net employment) and in tables 6.8 and 6.11 log of labour productivity. We start with the analysis of the manufacturing sector.

The main interest lies on the interaction terms of the fragmentation and the time dummies, because it captures the treatment effect. After the treatment happened the effects on total employment are rather similar, independent of using the balanced, the unbalanced sample, the vertically integrated firms- or all multi-plant comparison groups. Before the treatment happened there were rather small and mainly insignificant differences between the treatment group and the control group in the *restricted* sample. In the first period the reduction of total employment is around 28 percent[200] larger in treated firms than in firms of the control group. These values are increasing over time. Five years after fragmentation the treated firms have a 30 percent higher reduction in employment than the control group. We cannot find evidence that after five years the negative total employment effects are mitigated. Those results are supported by the *unrestricted* samples. The effects are even larger. While in the first post-treatment period the total employment decreases by around 30 percent, it is 40 percent after five years. One difference of the unrestricted sample is, that already one period before the treatment a large and significant relative employment decrease of around eight percent can be observed. Also

[200] This was calculated as follows: $\exp(-0.33) - 1$.

Variables	Restricted VI		Restricted All		Unrestr. VI		Unrestr. All	
$frag_i$	0.013	**	0.016	***	0.074	***	0.084	***
	(0.005)		(0.004)		(0.011)		(0.009)	
t^*_{-1}	0.000		0.000		0.030	***	0.032	***
	(0.002)		(0.002)		(0.003)		(0.002)	
t^*_0	-0.003		-0.002		0.062	***	0.065	***
	(0.004)		(0.003)		(0.005)		(0.003)	
t^*_1	-0.007		-0.009	*	0.108	***	0.112	***
	(0.005)		(0.003)		(0.008)		(0.005)	
t^*_2	-0.015	*	-0.018	***	0.140	***	0.139	***
	(0.006)		(0.004)		(0.011)		(0.007)	
t^*_3	-0.025	**	-0.028	***	0.153	***	0.144	***
	(0.008)		(0.005)		(0.013)		(0.008)	
t^*_4	-0.036	***	-0.038	***	0.169	***	0.147	***
	(0.009)		(0.006)		(0.014)		(0.009)	
t^*_5	-0.045	***	-0.047	***	0.184	***	0.149	***
	(0.011)		(0.007)		(0.015)		(0.010)	
$frag_i \times t^*_{-1}$	-0.012		-0.012	*	-0.035	***	-0.038	***
	(0.006)		(0.006)		(0.006)		(0.006)	
$frag_i \times t^*_0$	-0.016		-0.016		-0.079	***	-0.082	***
	(0.011)		(0.011)		(0.010)		(0.009)	
$frag_i \times t^*_1$	-0.328	***	-0.327	***	-0.346	***	-0.351	***
	(0.038)		(0.038)		(0.029)		(0.028)	
$frag_i \times t^*_2$	-0.325	***	-0.322	***	-0.370	***	-0.369	***
	(0.038)		(0.038)		(0.031)		(0.030)	
$frag_i \times t^*_3$	-0.343	***	-0.339	***	-0.431	***	-0.421	***
	(0.040)		(0.039)		(0.035)		(0.033)	
$frag_i \times t^*_4$	-0.338	***	-0.335	***	-0.444	***	-0.421	***
	(0.043)		(0.042)		(0.037)		(0.036)	
$frag_i \times t^*_5$	-0.363	***	-0.361	***	-0.513	***	-0.477	***
	(0.044)		(0.043)		(0.040)		(0.038)	
Log $Emp_{i,-2}$	0.985	***	0.983	***	0.930	***	0.926	***
	(0.005)		(0.003)		(0.007)		(0.005)	
$Age_{i,-2}$	-0.000		-0.000		-0.009	***	-0.008	***
	(0.001)		(0.000)		(0.001)		(0.001)	
Δ $Turnover_{i,-1}$	0.005		0.007		-0.000		0.000	
	(0.005)		(0.004)		(0.000)		(0.000)	
$Unionisation_{j,-2}$	0.081		0.063		0.080		0.046	
	(0.048)		(0.032)		(0.055)		(0.038)	
$Foreign_{i,-2}$	0.017		-0.000		0.026		0.036	
	(0.025)		(0.021)		(0.026)		(0.019)	
$R\&D_{j,-2}$	0.002		0.002		0.084		0.019	
	(0.003)		(0.003)		(0.089)		(0.014)	
Constant	0.015		0.037		0.386	***	0.388	***
	(0.042)		(0.028)		(0.057)		(0.037)	
Observations	22,048		41,904		49,200		115,989	
R-Square	.97		.973		.894		.883	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 6.6: Regression results for total employment effects in manufacturing using balanced restricted and unrestricted samples

the unbalanced panel analysis provides similar results with equally sized coefficients. See table D.10 on page 312 in the appendix.

The results for the indirect effect are less clear. The balanced samples do not show any significant impact of fragmentation on net employment immediately after the firm has fragmented. The indirect effect gets also smaller in size after five years, and remains insignificant in the restricted samples. In the unrestricted sample the indirect effect turns negative and highly significant. After five years net employment is 19 percent lower than in the control group. In the unbalanced samples we find similar results, with the only difference that in the short-run we have a positive employment effect in the restricted unbalanced sample. But this effect disappears completely after five years. See table D.11 on page 313 in the appendix.

Table 6.8 shows the results for sales per worker. After the treatment the labour productivity increases by about 23.9 percent and increases further. After five years labour productivity increases by about 26.4 – 29.8 percent. Again, the unbalanced samples support the results, however the restricted unbalanced sample has got negative but insignificant coefficients. See table D.12 on page 314 in the appendix.

Similar employment results appear in the service sector. The total employment effect is between -16 – -24 percent, where the absolute effect is larger in the unrestricted sample. Three years after the treatment employment is absolutely increasing further. In the restricted sample it reaches -18 percent and even -36 percent in the unrestricted sample. The unbalanced samples provide similar results. See table D.13 on page 315 in the appendix.

There is a large, but mostly insignificant, positive indirect employment effect. The employment in all other plant will immediately increase by 12 – 20 percent. This value gets smaller over time. The indirect employment effect seems to matter much more in the service sector. These results are supported again by the unbalanced sample. See

Variables	Restricted VI		Restricted All		Unrestr. VI		Unrestr. All	
$frag_i$	-0.357	***	-0.353	***	-0.229	***	-0.218	***
	(0.034)		(0.034)		(0.028)		(0.027)	
t^*_{-1}	0.000		0.000		0.030	***	0.032	***
	(0.002)		(0.002)		(0.003)		(0.002)	
t^*_0	-0.003		-0.002		0.062	***	0.065	***
	(0.004)		(0.003)		(0.005)		(0.003)	
t^*_1	-0.007		-0.009	*	0.108	***	0.112	***
	(0.005)		(0.003)		(0.008)		(0.005)	
t^*_2	-0.015	*	-0.018	***	0.140	***	0.139	***
	(0.006)		(0.004)		(0.011)		(0.007)	
t^*_3	-0.025	**	-0.028	***	0.153	***	0.144	***
	(0.008)		(0.005)		(0.013)		(0.008)	
t^*_4	-0.036	***	-0.038	***	0.169	***	0.147	***
	(0.009)		(0.006)		(0.014)		(0.009)	
t^*_5	-0.045	***	-0.046	***	0.185	***	0.149	***
	(0.011)		(0.007)		(0.015)		(0.010)	
$frag_i \times t^*_{-1}$	-0.012		-0.012		-0.031	***	-0.033	***
	(0.008)		(0.007)		(0.008)		(0.007)	
$frag_i \times t^*_0$	-0.030		-0.030		-0.077	***	-0.080	***
	(0.021)		(0.021)		(0.015)		(0.014)	
$frag_i \times t^*_1$	0.040		0.041		-0.044		-0.049	
	(0.044)		(0.044)		(0.033)		(0.032)	
$frag_i \times t^*_2$	0.043		0.046		-0.068		-0.068	
	(0.047)		(0.046)		(0.037)		(0.036)	
$frag_i \times t^*_3$	0.025		0.029		-0.129	**	-0.119	**
	(0.048)		(0.048)		(0.039)		(0.038)	
$frag_i \times t^*_4$	0.030		0.033		-0.142	***	-0.119	**
	(0.051)		(0.050)		(0.041)		(0.040)	
$frag_i \times t^*_5$	0.005		0.007		-0.211	***	-0.175	***
	(0.053)		(0.052)		(0.044)		(0.042)	
Log $Emp_{i,-2}$	0.987	***	0.984	***	0.931	***	0.927	***
	(0.005)		(0.003)		(0.007)		(0.005)	
$Age_{i,-2}$	-0.000		-0.000		-0.009	***	-0.008	***
	(0.001)		(0.001)		(0.001)		(0.001)	
Δ $Turnover_{i,-1}$	0.004		0.006		-0.000		0.000	
	(0.005)		(0.004)		(0.000)		(0.000)	
$Unionisation_{j,-2}$	0.092		0.069	*	0.086		0.049	
	(0.049)		(0.033)		(0.055)		(0.039)	
$Foreign_{i,-2}$	0.018		0.001		0.029		0.038	*
	(0.025)		(0.021)		(0.026)		(0.019)	
$R\&D_{j,-2}$	0.002		0.002		0.087		0.019	
	(0.003)		(0.003)		(0.089)		(0.014)	
Constant	-0.009		0.024		0.377	***	0.384	***
	(0.043)		(0.029)		(0.057)		(0.037)	
Observations	22,046		41,902		49,198		115,987	
R-Square	.967		.972		.892		.882	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 6.7: Regression results for indirect employment effects in manufacturing using balanced restricted and unrestricted samples

Variables	Balanced VI		Balanced All		Unbalan. VI		Unbalan. All	
$frag_i$	0.021	*	0.009		-0.016		-0.030	*
	(0.011)		(0.010)		(0.015)		(0.014)	
t^*_{-1}	0.022	***	0.017	***	0.019	***	0.017	***
	(0.005)		(0.004)		(0.004)		(0.003)	
t^*_0	0.028	***	0.023	***	0.022	**	0.018	***
	(0.008)		(0.006)		(0.007)		(0.004)	
t^*_1	0.036	**	0.036	***	0.016		0.008	
	(0.011)		(0.009)		(0.009)		(0.006)	
t^*_2	0.048	***	0.049	***	0.019		0.016	*
	(0.014)		(0.011)		(0.011)		(0.007)	
t^*_3	0.064	***	0.064	***	0.042	***	0.041	***
	(0.016)		(0.012)		(0.012)		(0.008)	
t^*_4	0.066	***	0.071	***	0.049	***	0.058	***
	(0.019)		(0.014)		(0.013)		(0.009)	
t^*_5	0.070	**	0.079	***	0.055	***	0.075	***
	(0.022)		(0.016)		(0.015)		(0.009)	
$frag_i \times t^*_{-1}$	-0.020		-0.016		0.021		0.022	
	(0.020)		(0.019)		(0.040)		(0.040)	
$frag_i \times t^*_0$	-0.031		-0.027		0.046		0.049	
	(0.028)		(0.027)		(0.039)		(0.038)	
$frag_i \times t^*_1$	0.214	***	0.212	***	0.243	***	0.251	***
	(0.041)		(0.040)		(0.042)		(0.041)	
$frag_i \times t^*_2$	0.165	***	0.163	***	0.206	***	0.209	***
	(0.049)		(0.048)		(0.044)		(0.044)	
$frag_i \times t^*_3$	0.219	***	0.217	***	0.243	***	0.244	***
	(0.044)		(0.042)		(0.043)		(0.042)	
$frag_i \times t^*_4$	0.192	***	0.185	***	0.197	***	0.188	***
	(0.043)		(0.042)		(0.044)		(0.043)	
$frag_i \times t^*_5$	0.234	***	0.222	***	0.261	***	0.241	***
	(0.052)		(0.050)		(0.049)		(0.047)	
Log $Prod_{i,-2}$	0.870	***	0.857	***	0.714	***	0.707	***
	(0.022)		(0.019)		(0.023)		(0.014)	
$Age_{i,-2}$	-0.004	**	-0.003	**	-0.004	***	-0.003	***
	(0.002)		(0.001)		(0.001)		(0.001)	
$Unionisation_{j,-2}$	-0.224	*	-0.140		-0.230	**	-0.109	*
	(0.095)		(0.074)		(0.072)		(0.046)	
$Foreign_{i,-2}$	0.212	***	0.224	***	0.221	***	0.202	***
	(0.035)		(0.030)		(0.025)		(0.018)	
$R\&D_{j,-2}$	0.013	**	0.011	*	0.124		0.013	
	(0.005)		(0.004)		(0.120)		(0.027)	
Constant	0.741	***	0.739	***	1.336	***	1.340	***
	(0.109)		(0.096)		(0.114)		(0.072)	
Observations	22,039		41,834		49,135		115,815	
R-Square	.69		.67		.577		.561	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 6.8: Regression results for firm average labour productivity effects in manufacturing using balanced restricted and unrestricted samples

Variables	Restricted VI		Restricted All		Unrestr. VI		Unrestr. All	
$frag_i$	0.009		0.001		0.091	***	0.041	***
	(0.007)		(0.003)		(0.017)		(0.011)	
t^*_{-1}	-0.003		0.004	**	0.059	***	0.051	***
	(0.002)		(0.001)		(0.005)		(0.002)	
t^*_0	-0.007		0.007	***	0.124	***	0.105	***
	(0.004)		(0.002)		(0.010)		(0.004)	
t^*_1	-0.011	*	0.010	***	0.210	***	0.180	***
	(0.005)		(0.003)		(0.015)		(0.005)	
t^*_2	-0.016	*	0.012	***	0.293	***	0.234	***
	(0.006)		(0.003)		(0.020)		(0.007)	
t^*_3	-0.020	**	0.014	**	0.339	***	0.255	***
	(0.008)		(0.004)		(0.023)		(0.008)	
$frag_i \times t^*_{-1}$	0.034		0.028		-0.038	**	-0.030	*
	(0.024)		(0.023)		(0.013)		(0.012)	
$frag_i \times t^*_0$	0.038		0.024		-0.054		-0.035	
	(0.025)		(0.024)		(0.029)		(0.028)	
$frag_i \times t^*_1$	-0.179	*	-0.201	**	-0.277	***	-0.246	***
	(0.071)		(0.071)		(0.066)		(0.064)	
$frag_i \times t^*_2$	-0.203	*	-0.231	**	-0.390	***	-0.329	***
	(0.079)		(0.079)		(0.077)		(0.075)	
$frag_i \times t^*_3$	-0.204	*	-0.239	**	-0.440	***	-0.353	***
	(0.084)		(0.084)		(0.083)		(0.080)	
Log $Emp_{i,-2}$	0.986	***	1.001	***	0.941	***	0.943	***
	(0.006)		(0.004)		(0.012)		(0.004)	
$Age_{i,-2}$	0.000		0.001		-0.011	***	-0.011	***
	(0.001)		(0.000)		(0.002)		(0.001)	
Δ $Turnover_{i,-1}$	-0.000		0.000		0.001		0.002	
	(0.000)		(0.000)		(0.001)		(0.001)	
$Unionisation_{j,-2}$	-0.055		-0.078	*	-0.039		-0.130	*
	(0.046)		(0.034)		(0.162)		(0.055)	
$Foreign_{i,-2}$	0.041		-0.011		0.039		0.053	
	(0.032)		(0.024)		(0.058)		(0.034)	
$R\&D_{j,-2}$	-0.000		-0.000		0.003		-0.003	
	(0.000)		(0.000)		(0.004)		(0.004)	
Constant	0.045		0.010		0.376	***	0.382	***
	(0.025)		(0.013)		(0.063)		(0.027)	
Observations	10,806		61,470		24,183		163,568	
R-Square	.972		.973		.815		.827	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 6.9: Regression results for total employment effects in tradable service sector using balanced restricted and unrestricted samples

Variables	Restricted VI		Restricted All		Unrestr. VI		Unrestr. All	
$frag_i$	-0.351	***	-0.357	***	-0.300	***	-0.349	***
	(0.047)		(0.046)		(0.046)		(0.045)	
t^*_{-1}	-0.003		0.004	**	0.059	***	0.051	***
	(0.002)		(0.001)		(0.005)		(0.002)	
t^*_0	-0.007		0.007	***	0.124	***	0.105	***
	(0.004)		(0.002)		(0.010)		(0.004)	
t^*_1	-0.012	*	0.010	***	0.210	***	0.180	***
	(0.005)		(0.003)		(0.015)		(0.005)	
t^*_2	-0.016	*	0.012	***	0.293	***	0.234	***
	(0.006)		(0.003)		(0.020)		(0.007)	
t^*_3	-0.020	**	0.014	**	0.339	***	0.255	***
	(0.008)		(0.004)		(0.023)		(0.008)	
$frag_i \times t^*_{-1}$	0.061		0.054		-0.018		-0.010	
	(0.047)		(0.047)		(0.025)		(0.024)	
$frag_i \times t^*_0$	0.069		0.056		-0.027		-0.008	
	(0.048)		(0.048)		(0.038)		(0.037)	
$frag_i \times t^*_1$	0.179	*	0.157		0.113		0.144	
	(0.091)		(0.091)		(0.080)		(0.078)	
$frag_i \times t^*_2$	0.155		0.127		0.000		0.061	
	(0.100)		(0.099)		(0.090)		(0.088)	
$frag_i \times t^*_3$	0.154		0.119		-0.050		0.037	
	(0.104)		(0.103)		(0.095)		(0.093)	
Log $Emp_{i,\,-2}$	0.988	***	1.001	***	0.942	***	0.943	***
	(0.006)		(0.004)		(0.012)		(0.004)	
$Age_{i,\,-2}$	0.000		0.001		-0.011	***	-0.011	***
	(0.001)		(0.000)		(0.002)		(0.001)	
Δ $Turnover_{i,\,-1}$	-0.000		0.000		0.001		0.002	
	(0.000)		(0.000)		(0.001)		(0.001)	
$Unionisation_{j,\,-2}$	-0.059		-0.078	*	-0.040		-0.130	*
	(0.046)		(0.034)		(0.162)		(0.055)	
$Foreign_{i,\,-2}$	0.040		-0.012		0.029		0.050	
	(0.029)		(0.023)		(0.058)		(0.034)	
$R\&D_{j,\,-2}$	-0.000		-0.000		0.003		-0.003	
	(0.000)		(0.000)		(0.004)		(0.004)	
Constant	0.040		0.009		0.373	***	0.381	***
	(0.024)		(0.013)		(0.063)		(0.027)	
Observations	10,806		61,470		24,183		163,568	
R-Square	.971		.973		.813		.826	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 6.10: Regression results for indirect employment effects in tradable service sector using balanced restricted and unrestricted samples

table D.14 on page 316 in the appendix.

Table 6.11 gathers the results for labour productivity. The size and sign of the treatment coefficients depend on the sample and control group chosen. The only common factor of all results is that they are insignificant. The immediate effect is between 4.1 – 14.5 percent. Three years later the impact remains with 7.5 – 16.2 percent dispersed. The unbalanced samples show an immediate, significant and positive effect, even though the significance disappears over time and the coefficients can even turn negative. See table D.15 on page 317 in the appendix.

6.6. Conclusions

The main aim of this chapter was to illustrate how fragmentation may affect the performance of a firm. To be more specific, we examined the impact of plant closure on total employment, employment in the remaining plants, and labour productivity. Plant closure is taken to be a measure of fragmentation because we consider plants which were vertically linked to production in other plants within the firm. Productivity is measured as sales per worker. We use a Difference-in-Differences approach, where we compare the performance of firms which closed a vertically integrated plant with firms which did not close one.

Fragmentation leads in the short- (one year) and in the medium-run (3 – 5 years) to a large decrease in total employment and the effects absolutely increase over time. In manufacturing, immediately after a firm closes a plant it will reduce total employment on average by 14 (-17%). After five years the value increases up to 18 workers (-23%). There is no evidence of a rebound effect. Similar results are found in the tradable service sector. One year after the firm fragments it will reduce total employment by 5 workers (-16%), but 3 years later it will decrease to 4 workers (-13%).

If we consider net employment, the total employment minus employment of the exiting

Variables	Restricted VI		Restricted All		Unrestr. VI		Unrestr. All	
$frag_i$	0.067	*	0.083	**	0.032		0.071	**
	(0.032)		(0.026)		(0.027)		(0.025)	
t^*_{-1}	0.008		0.027	***	0.019	*	0.028	***
	(0.010)		(0.003)		(0.008)		(0.003)	
t^*_0	-0.000		0.043	***	0.017		0.042	***
	(0.016)		(0.005)		(0.013)		(0.004)	
t^*_1	0.002		0.057	***	-0.007		0.033	***
	(0.023)		(0.008)		(0.017)		(0.006)	
t^*_2	-0.013		0.066	***	-0.047	*	0.031	***
	(0.029)		(0.011)		(0.021)		(0.007)	
t^*_3	-0.017		0.076	***	-0.053	*	0.045	***
	(0.032)		(0.013)		(0.023)		(0.008)	
$frag_i \times t^*_{-1}$	-0.072		-0.087		-0.021		-0.030	
	(0.050)		(0.049)		(0.040)		(0.039)	
$frag_i \times t^*_0$	-0.059		-0.099		-0.113	*	-0.138	**
	(0.063)		(0.061)		(0.048)		(0.046)	
$frag_i \times t^*_1$	0.135		0.083		0.040		-0.000	
	(0.071)		(0.068)		(0.065)		(0.063)	
$frag_i \times t^*_2$	0.125		0.049		0.014		-0.064	
	(0.083)		(0.078)		(0.079)		(0.076)	
$frag_i \times t^*_3$	0.150		0.058		0.072		-0.029	
	(0.099)		(0.094)		(0.081)		(0.077)	
Log $Prod_{i,-2}$	0.792	***	0.799	***	0.735	***	0.723	***
	(0.033)		(0.017)		(0.020)		(0.009)	
$Age_{i,-2}$	-0.003		-0.003	**	-0.005	***	-0.002	**
	(0.002)		(0.001)		(0.002)		(0.001)	
$Unionisation_{j,-2}$	-0.005		-0.145		-0.156		0.050	
	(0.196)		(0.085)		(0.146)		(0.058)	
$Foreign_{i,-2}$	-0.009		0.020		0.195	***	0.210	***
	(0.067)		(0.059)		(0.053)		(0.035)	
$R\&D_{j,-2}$	0.001		0.000		0.027		0.026	
	(0.001)		(0.000)		(0.026)		(0.026)	
Constant	0.898	***	0.732	***	1.219	***	1.073	***
	(0.156)		(0.078)		(0.107)		(0.046)	
Observations	10,764		61,266		24,062		163,133	
R-Square	.622		.598		.589		.562	

* p<0.05, ** p<0.01, *** p<0.001

Table 6.11: Regression results for firm average labour productivity effects in tradable service sector using balanced restricted and unrestricted samples

local unit, then the results reveal that one year after the treatment there is no significant effect appearing but is getting absolutely larger over time. After a manufacturing firm fragmented, it will reduce employment in all other plants by 4.5 more workers in the medium-run. Regression results support partly the significant negative effect, if we consider the unrestricted sample. We find a positive effect in the tradable service sector. Employment will increase by 0.85 workers because of the change in the indirect effect between the first and the third period after the treatment. Regression results find a positive, but statistically not significant result.

Fragmentation is correlated with large productivity gains for manufacturing firms. Productivity increase immediately by 27 percent and remains 15 percent higher after 5 years. Regression results suggest that productivity may even increase further over time. We do not find a clear picture for the tradable services.

Concluding, we could not find evidence that firms start specialising and increase the employment five years after the treatment. In contrast, the negative employment effects are increasing in size over time. We find strong evidence that fragmentation affects the productivity of manufacturing firms positively, but the results for the tradable service sector are ambiguous. Fragmentation seems to affect manufacturing and tradable-service firms differently.

7. Conclusion

In this thesis we have attempted to provide a comprehensive and detailed analysis of the organisational structure of UK firms over the period 1997 – 2008. We focused in particular on three key questions:

1. How fragmented are UK firms and has the degree of fragmentation changed over time?
2. What common theories can explain the organisational structure of UK firms?
3. What are the effects of fragmentation on the employment and labour productivity of UK firms?

We focused on organisational and spatial fragmentation. The former concept captures the extent to which intermediate inputs are sourced from the market, and the latter concept captures the extent to which the internal production process of a company is geographically dispersed across the UK. To calculate a degree of vertical integration and to identify the linkages between headquarters and vertically integrated local units we used input-output tables. The main foundation of this work was the Business Structure Database (BSD) provided by the Office for National Statistics (ONS). This large scale dataset includes the great majority of UK companies for the period 1997 – 2008. It includes firm level as well as plant (local unit) level information, which is required to calculate our fragmentation measure. It further allows us to analyse both the manufacturing and the tradable service sector. In terms of employment and output, the latter is an increasingly important part of the UK economy.

Because of its importance we provided a detailed description of the BSD and its virtues and limitations in chapter 3. The BSD is regularly and quickly updated. For example, at the end of 2011, data for 2010 was already online. This will enable researchers in the future, for example, to look at the effects of the financial crisis on the organisational structure of firms.

In chapter 4 we examined whether UK firms had become more fragmented or integrated over the last decade. Although this is a relatively short period, we found evidence of striking changes in the organisation of UK firms. The analysis of the *organisational* dimension revealed that the degree of vertical integration for the average firm was extremely low, even if only vertically integrated firms were considered. In short, this means that UK firms tend to source the great majority of their intermediate inputs from separate firms, and not from within their own organisation. In the manufacturing sector the picture was quite clear. The proportion of vertically integrated firms decreased from 3 percent in 1997 to 2 percent in 2008 and the degree of vertical integration from 0.16 percent to 0.09 percent. This means that the average firm only sourced 0.09 percent of its demanded intermediate inputs internally. Manufacturing firms became more fragmented, regardless whether all or only multi-plant firms were considered. In the tradable service sector the results were rather similar but at a significant lower level. The proportion of vertically integrated firms decreased from 0.6 to 0.2 percent and the degree of vertical integration decreased from 0.04 to 0.016 percent if all firms were considered. The share of vertically integrated firms was lower in the service sector than in manufacturing, but if a service firm was vertically integrated, it tends to be at a higher degree.

We could only measure the *spatial dispersion* of vertically integrated local units, therefore the analysis of spatial fragmentation considered only vertically integrated local units. The average dispersion of vertically integrated local units increased over the last decade for manufacturing (from 63km to 75km) and the tradable service sector (from 60km to 80km).

A decomposition of the change in the degree of vertical integration and the spatial dispersion showed that the entry of new firms caused almost the entire decline in the degree of vertical integration and newly vertically integrated firms caused the increase in spatial dispersion.

We concluded therefore that UK firms had become more fragmented. This statement is supported by the observation that firms became significantly smaller, the number of manufacturing firms fell significantly, the number of service firms skyrocketed and the productivity of manufacturing firms increased. These observations fit into the specialisation discussion. For example, manufacturing firms outsource non-core activities, like services, which leads to smaller manufacturing firms and a larger service sector. Through specialisation, productivity will increase too. Still, we cannot exclude other explanations for firms becoming smaller. First of all, technological improvements and new production methods could have reduced the average size of a firm. The change in the mode of production is the main explanation of Choi and Spletzer (2011) for US firms and local units becoming smaller. Braguinsky et al. (2011) connect the shrinking size of firms in Portugal with strict labour market protection laws. What policies could affect the average firm size in the UK? An important determinant of the UK firm composition could be the VAT threshold. VAT was introduced in the UK in 1973 and firms above a turnover of £5,000 had to register, but this values had already doubled to £10,000 by 1978.[201] The VAT threshold increased above the inflation rate a second time in 1991 from £25,400 to £35,000. Since then, the threshold was only inflation adjusted. Recently, the threshold reached £73,000 in 2011. What are the consequences of a real VAT threshold increase, as in the 1970s and 1991? At a first glance, a larger amount of small firms will appreciate a decrease in costs and might increase the number of smaller firms. This should lead to a reduction of the average firm size. However, in our data only firms above the VAT threshold are recorded. Therefore the average size of a firm will increase, if we assume that sales and employment are positively related. On the other hand, if labour productivity increases faster than the increase in the VAT threshold, smaller firms will pass the threshold and average size over the threshold will fall.

[201] See Seely (2011) for a comprehensive description of the UK VAT threshold.

Concluding, many factors can actually cause the shrinking UK firm size. Further research is required to identify the extent to which fragmentation, other technological developments or data issues are the key determinants of the observed fall in average firm size.

In chapter 5 we examined whether existing economic theories could explain why firms choose a particular organisational structure, and which determinants were most important. The organisational structures of concern were single-plant vs. multi-plant firm (first stage), fragmented vs. integrated multi-plant firm (second stage) and spatially concentrated vs. dispersed multi-plant firm (third stage). For the first stage we found that market concentration had a positive effect on becoming a multi-plant firm in the manufacturing and tradable service sector, but it seemed to matter more in the latter. We found only a small significant impact of capital intensity in manufacturing. External R&D intensity had a significant positive effect in the tradable service sector. Technology mattered in both sectors. In general, firms closer to the technological frontier were more likely to become multi-plant firms. While technological industry heterogeneity had a negative effect on manufacturing firms it was the opposite for the tradable service sector.

For the second stage we found that technology had the same effect in every sector. Proximity to the technological frontier led to a higher probability of being vertically integrated. The more technologically heterogeneous an industry was, the less likely would be firms within that industry vertically integrated. R&D intensities, to capture knowledge capital, were positively correlated with being vertically integrated in the tradable service sector, even though we did not find many significant coefficients. In manufacturing, external R&D intensity was positively correlated with being vertically integrated, in-house R&D negatively.

In the third stage we could not find evidence that factor price differences affected the spatial distribution of UK firms. Knowledge capital could also not explain the spatial distribution. We found that, in general, independent of the sector, large firms, which were close to the technological frontier and in a concentrated market, were more dispersed. Additionally, being located in a populated area had a positive impact on being concentrated for tradable service firms.

The main problem of this chapter is the fact that many of the determinants of organisational structure are endogenous because they are chosen by the firm itself. We tried to mitigate this problem by using fixed effects estimators and lagged independent variables. Still, we could not capture time-variant unobservable factors. In the future, industry variables like R&D expenditures and industry heterogeneity from other countries could be used as an instrument, even though the variables may still be correlated with UK unobservables. Another problem was that, by using a within-group estimator, only small changes could be captured and measurement errors may led to downwardly biased coefficients. Further investigations are required in the second stage of analysis with regards to the R&D measures. Even though in-house and external R&D intensities were highly correlated, they had opposite signs. In stage 3, further research is required, because our main explanations for geographical dispersion, factor price differences and agglomeration, do not seem to be able to explain a spatially dispersed production process of manufacturing firms within the UK. Other theoretical models may be needed.

In chapter 6 we examined the consequences of fragmentation. Specifically, we looked at how the closure of a vertically integrated local unit will affect total employment, indirect employment (that is employment in the remaining parts of the firm) and labour productivity of a firm. The total employment effect was straight forward. In manufacturing, immediately after a firm closes a plant, it reduces total employment on average by 14 workers (-17%). After five years the value increases to 18 workers (-23%). Similar results were found in the tradable service sector. One year after the firm fragments it reduces total employment by 5 workers (-16%), but 3 years later by 4 workers (-13%).

The key finding of the chapter was that the employment losses were not compensated elsewhere in the firm. One year after the treatment, there was no significant indirect employment effect appearing, regardless the sector. After five years, the indirect employment for manufacturing firms led to a further reduction of employment in all other plants by 4.5 workers. Regression results supported partly the significant negative effect, when we considered the unrestricted sample. We found a positive effect in the tradable service sector after three years. Employment increased by 0.85 workers, because of the change in the indirect effect between the first and the third period after the treatment. Regression results were positive, but statistically not significant.

Fragmentation was correlated with large productivity gains for manufacturing firms. Productivity increased immediately by 27 percent and remained 15 percent higher after 5 years. Regression results suggested that productivity may even increase further over time. One explanation could be that through fragmentation firms started to specialise and became therefore more productive by focusing on their core activities. A more mundane explanation could be that firms were just closing the least productive local units. We did not find a clear picture about productivity changes for the tradable service sector.

We used a Difference-in-Differences (DiD) estimator for our analysis. However, an important caveat is the extent to which the estimates can be interpreted as the causal effect of fragmentation. Although the control group are observably "similar" to the treatment group, fragmentation is a choice which may well be correlated with other unobserved shocks. Thus the counterfactual — what would have happened in the absence of fragmentation — may not be revealed by the control group. For future research we want to add propensity score matching, a method, which compares treated firms with the most similar firms from the control group. However, also this method will not be able to identify the "real" counterfactual. We also want to compare the results with the closure of horizontally linked local units. This will shed light on the topic if the firm level productivity and employment depends on the type of closed local unit.

The organisational structure of firms is continuously changing. The ICT revolution, new and more (human) capital intensive products and the "death of distance" have created an environment in which fragmentation could evolve easily. Our analysis showed that the time of fragmentation is not over yet. The number of large firms producing large parts of their intermediate inputs internally is decreasing, instead thousands of small single-plant firms arise every year. These structural changes can have significant *consequences* for the *welfare* of the UK. Specialisation can lead to a positive effect on the aggregate productivity level. The United Kingdom may become more competitive in a globalised world and can secure, or even improve, its trading position. If the production chain fragmented domestically, then new jobs can be created. If production stages are offshored or outsourced abroad, then the employment loss can be greater than the gain of jobs through specialisation. Newly created jobs will not be distributed equally over all jobs with different skill level. The UK has a comparative advantage in skill-intensive jobs, therefore specialisation will have positive effects on employment and wages for highly skilled people. However, outsourced low-skilled jobs will have a negative impact for unskilled UK workers. Wages will become lower because of a lower demand for UK low skilled workers.

Ignoring the international dimension, the trend towards small single-plant firms can have an impact on market structure. Many small firms can be an indicator for increased competition, which leads to lower prices and increasing welfare for consumers. However, smaller firms might not be able to provide services for employees like larger companies. For example, fringe benefits, like training programmes, career advancement or even child care, will only be relevant after a certain firm size has been surpassed. Also, smaller firms pay lower wages on average than larger companies (Oi and Idson, 1999). Furthermore, Mayo and Murray (1991) show that firm size is negatively correlated with firm failure. Therefore smaller firms in general will offer less stable jobs.

Concluding, the structure of UK firms has changed, which leads to smaller firms, which are more productive. The effect of this change on the welfare of the UK can be ambiguous and requires further research.

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Appendices

A. Literature Review

A.1. The Maddigan (1981) Measure: A Numerical Example

A numerical example is provided which should help to understand the mechanics behind the vertical integration measure by Maddigan (1981). To keep it as simple as possible three industries called 1, 2 and 3 and one firm are assumed. Further factors like value added, private consumption etc. are assumed to be zero.

Matrix X shows the value of goods from industry i delivered to industry j and Z the total output of an industry i. For example, industry 2 demands goods of value 5 from industry 1. The total output of industry 2 is 17.

$$\mathbf{X} = \begin{pmatrix} 2 & 5 & 4 \\ 6 & 2 & 9 \\ 7 & 3 & 3 \end{pmatrix}, \qquad \mathbf{Z} = (11, 17, 13)$$

In the second step two matrices containing relative net inputs (matrix A) and relative net output shares (matrix B) are created.[202] Negative values represent inputs and positive values outputs.

$$\mathbf{A} = \begin{pmatrix} 1 & -0.42 & -0.44 \\ -1.2 & 1 & -2.25 \\ -1.75 & -0.21 & 1 \end{pmatrix}, \qquad \mathbf{B} = \begin{pmatrix} -1 & 0.56 & 0.44 \\ 0.4 & -1 & 0.6 \\ 0.7 & 0.3 & -1 \end{pmatrix}$$

In the third step matrices C and D are calculated. Those are calculated for every firm

[202] The exact formula used is $A = I - [x_{ij}/(z_j - x_{ij})] + [y_{ij}]$ and $B = [x_{ij}/(z_i - x_{ii})] - [y_{ij}] - I$, where I is the identity matrix and y_{ij} exists to offset the first term in brackets if $i = j$.

separately and keeps only those rows and columns (industries) in which the firm is active. Firm 1 is at the beginning only active in industry 1, therefore $C1 = 1$ and $D1 = -1$. Equation 2.3 in chapter 2 leads to $vi_1^{madd} = 1 - 1/((1)(1)) = 0$.

Firm 2 is active in industry 1 and industry 2.

$$\mathbf{C2} = \begin{pmatrix} 1 & -0.44 \\ -1.75 & 1 \end{pmatrix}, \qquad \mathbf{D2} = \begin{pmatrix} -1 & 0.44 \\ 0.7 & -1 \end{pmatrix}$$

Therefore $vi_2^{madd} = 1 - \dfrac{1}{(1+0.44^2)(1+1.75^2)(1+0.44^2)(1+0.7^2)} = 0.47$

Finally the last firm has got a plant in every industry, so $C3 = A$ and $D3 = B$. This results in $vi_3^{madd} = 0.99$, meaning that this company is completely vertically integrated.

B. Are UK Firms Becoming More Fragmented?

Additional information for chapter 4 is provided here. In some graphs, additionally to the manufacturing and the tradable-service sector, the non-tradable sector is included. At the beginning of writing the thesis analysis included this sector as well, but, because vertical integrated firms hardly appear, we dropped it later.

B.1. Description of Databases Used Besides BSD and ARD

FAME

We want to take a closer look at the distance between local units and their headquarters. The Business Structure Database (BSD) does not include information on whether the location of the enterprise refers to the headquarters or just to the reporting unit. The Financial Analysis Made Easy Database (FAME) can be used to identify the headquarters. This database of Bureau van Dijk (BvD) offers financial information about all British firms (corporations) which are registered at the Companies House. Additionally to financial information, it also includes a company registration number (CRN) and a postcode for the location of the headquarters. All in all, 7m companies are included. However, 4m are already inactive.[203] In this thesis FAME data from 2009 is used. Because it is a live database it cannot be controlled for changes in the headquarters location over time. This database is available at BvD's homepage at `http://www.bvdinfo.com`, access on 17/05/2010.

National Statistics Postcode Directory

The National Statistics Postcode Directory (NSPD) of February 2009 includes Eastings and Northings identifiers, which are used to measure the distance between local units.

[203] See `http://www.bvdep.com/pdf/brochure/Fame.pdf`, access on 12/11/09.

2.47m postcodes are included. This database is available at Edina's UKBORDES site at http://edina.ac.uk/ukborders/, access on 17/05/2010.

Input-Output Tables

We use input-output tables for the UK to calculate the degree of vertical integration of UK plants. The Use-matrix shows how many goods are transferred between the industries. To be more precise, the Use matrix is a product $\times$ industry matrix, where the product can be different from the industry classification. It is not always the case that only companies from an industry j produce goods from sector j, for example a company can produce goods of different industries, but it is still regarded as company of its main business. To get a measure of vertical integration we nevertheless assume that the product side of the matrix represents the supplying and the industry side the demanding industry.

Input-output tables are annually generated for the UK. They are constructed through data source supplied by the Office for National Statistics (ONS), other government departments (for example the Bank of England) and non-governmental sources (for example the association of British insurers), whereby the main ONS source is the Annual Business Inquiry (ABI) (Mahajan, 2006). About 13,000 firms received in 2005/06 an industry specific statutory survey about intermediate input consumption. Input-output tables are available at ONS homepage at http://www.statistics.gov.uk/about/methodology_by_theme/inputoutput/default.asp, access on 17/05/2010.

B.2. Descriptive Statistics of the UK Economy Without Dropping Outliers

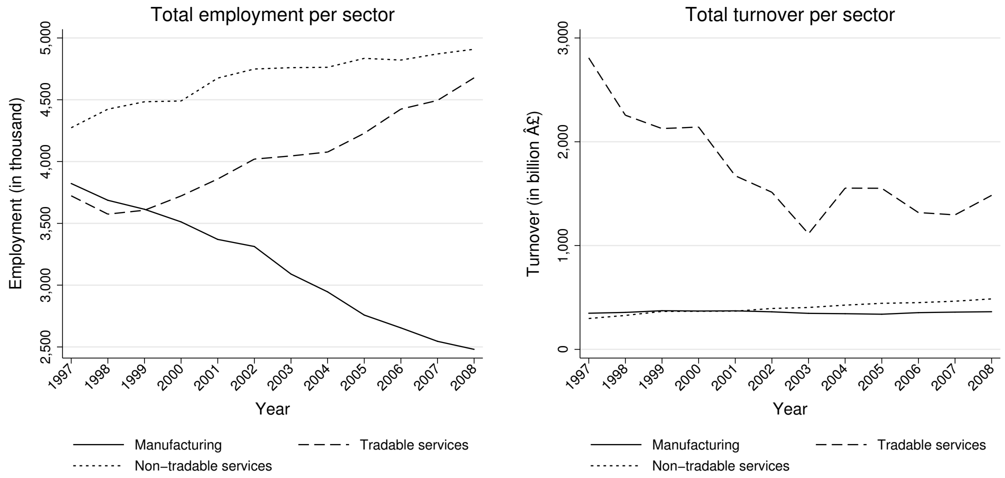

Figure B.1: Size of sample sectors according to employment and turnover, including outliers

B.3. Basic Mean Distance Measure

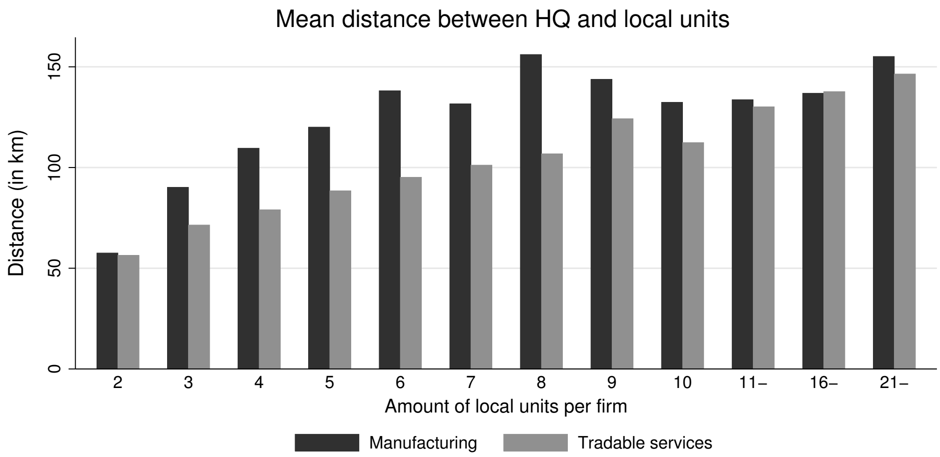

Figure B.2: Mean distance between headquarters and local units

B.4. Calculation of the Measure of Vertical Integration Using Stata

How to measure vertical integration was already mentioned in section 4.4.1. To summarise, the idea is to use input-output tables to find the intermediate input structure of a plant. If a firm consists of multiple local units we can identify those local units, which produce outputs, which are used as intermediate inputs for other local units within the same company. Input-output tables enable us further to calculate a measure for the degree of vertical integration. To put it differently, to generate the degree of backward vertical integration of a plant A, it is checked how many other plants of the same enterprise, to which plant A belongs to, are producing goods which are intermediate inputs for plant A. The intermediate input shares of all intermediate inputs supplying local units are added up. To apply those ideas empirically, the following description explains how to implement the calculation of backward vertical integration in Stata. The Stata version used in the Virtual Microdata Laboratory (VML) is 9.2. Two datasets are needed: the Business Structure database (BSD) and UK input-output tables. The following steps were conducted:

1. Because input-output tables are categorised into industries different to the SIC 2003 which is used in the BSD, the BSD has to be made consistent first. The industry classification of the input-output table can be easily matched with the SIC 03.[204]

2. In the next step relative input values are calculated in the input-output tables. Because input-output tables have supplying industries in rows and demanding industries in columns the whole input-output table has to be transposed.

3. Finally, the input-output matrix has to be reshaped into long format, so a list is gained showing the intermediate inputs supplying industries for each SIC sector

[204] Look-up tables can be found at the ONS homepage. See `http://www.statistics.gov.uk/about/methodology_by_theme/inputoutput/`, access: 10/02/10.

After that, the input-output table and the BSD are ready to be merged. The following Stata code was used for the calculation of the vertical integration measure:

To avoid confusion with the notation, the three different SIC variables are `lu_sic_4` for the four digit SIC code of local units of the BSD, `lu_sic_io` the input-output table consistent SIC code of local units of the BSD and finally `supply_sic` for the intermediate input supplying companies gained from the input-output tables.

A loop is used for the whole observation period:

```
forvalues i = 1997(1)2008{
```

The BSD data with consistent SIC codes for each year is loaded:

```
use if year == `i' using "io_bsd"
```

Because of the massive size of the data and the resource intensive way of calculation the sample has to be reduced. First of all, single plant firms are by definition not vertically integrated and can be dropped.

```
bysort entref: keep if _N > 1
```

Another assumption is that, if a company has multiple local units which are in the same 2-digit industry but in a different 4-digit industry, those local units will be classified as vertically integrated. To achieve that, only one local unit per 4-digit SIC sector per company is kept.

```
bysort entref lu_sic_4: keep if _n == 1
```

A variable is created to indicate how many plants with different 4-digit SIC codes exist within the same 2-digit SIC sector. Then the BSD is merged with the input-output tables. Because all industries of the input-output tables have to be connected to one local unit of the BSD, the command `joinby` has to be used. After the merge all intermediate input supplying sectors of local units are available.

```
bysort entref lu_sic_io: gen plants_in_sic = _N
bysort entref lu_sic_io: gen plants_in_sic_num = _n

sort lu_sic_io
joinby lu_sic_io using "io_long_rel_back", unmatched(master)
```

Now the final selection can be conducted. If there is only one kind of plants of a specific 4-digit sector within a firm all of those observations can be dropped. Only one representative local unit with the relative share of intermediate inputs has to be kept.

```
drop if supply_sic == lu_sic_io & plants_in_sic == 1
drop if plants_in_sic > 1 & plants_in_sic_num > 1
```

The following code is the crucial part of the do file. The `supply_sic` shows the SIC code of intermediate input supplying industries. The code checks for every `supply_sic` of a local unit if any other local units within a firm exist which have a similar SIC code. If that is the case the relative share of intermediate inputs used by local unit is allocated to a vertical integration variable. The first command lines are needed to calculate the maximum amount of iteration for every year.

```
egen maxrows = count(year), by(entref)
su maxrows
local J = r(max)
sort entref luref supply_sic
gen vi_b=.
```

```
forvalues j = 1(1)`J'{
di "." _c
quietly by entref: replace vi_b = use if supply_sic == lu_sic_io[`j']
}
replace vi_b = 0 if vi_b == .
save "iot_vi_b_matched_`i'", replace
```

The last command lines generate the share of in-house intermediate inputs used by local units. Finally, the share can be merged with the BSD and the vertical integration measure is added to the BSD sample.

```
egen sum_vi_b = sum(vi_b), by(entref lu_sic_io)
bysort entref lu_sic_io: keep if _n==1
keep entref lu_sic_io sum_vi_b
save "io_bsd_vi_b_`i'", replace

use if year==`i' using "io_bsd"
sort entref lu_sic_io
merge entref lu_sic_io using io_bsd_vi_b_`i'
replace sum_vi_b=0 if missing(sum_vi_b)

save "bsd_vi_b_`i'", replace
}
```

B.5. Check of the IO Measures

We checked if the usage of a different input-output table would change the result significantly. The input-output table of 1997 was used to calculate the degree of vertical integration for the year 1997 and was then compared with the results of 1997 obtained by using the input-output table of 2002. This analysis was only conducted for the manufacturing sector using the sample dropping the largest 0.5 percent of firms. Table B.1 reveals that the differences between the input-output table 1997 and input-output tables 2002 calculations are negligible, for the local unit as for the firm level.

		IOT 2002	IOT 1997
Local units	vib of all local units	0.0042	0.0042
	vib of mp local units	0.031	0.0313
	vib of vi local units	0.0574	0.0603
	share of vi local units to total	0.0728	0.0704
	share of vi local units to mp	0.5408	0.52
Firms	vib of all firms	0.0247	0.0248
	vib of vi firms of mp	0.0479	0.0479
	share of vi local units to total	0.0277	0.0275
	share of vi local units to mp	0.5155	0.51

vib . . . degree of backward vertical integration
mp . . . multi-plant
vi . . . vertical integrated

Table B.1: Comparison of backward vertical integration using input-output tables 1997 and 2002

B.6. The Local Unit Vertical Integration Measure

In figure B.3 we capture the degree of vertical integration of the average local unit. In general, because of the high share of single-plant firms, the average degree of vertical integration is rather low if all firms are considered. The degree is fluctuating, especially for the service sector. The more local units per firm are considered the more fluctuating the picture gets. In the manufacturing sector the picture is quite clear. If all firms are considered, the degree of vertical integration is decreasing, while in 1997 the average plant sourced around 0.8 percent of intermediate inputs internally, it was only around 0.6 percent in 2008. Multi-plant firms are keeping the same degree of vertical integration. Approximately 4.8 percent of intermediates have been produced in-house. For the vertically integrated firm sample the degree is around 8 percent.

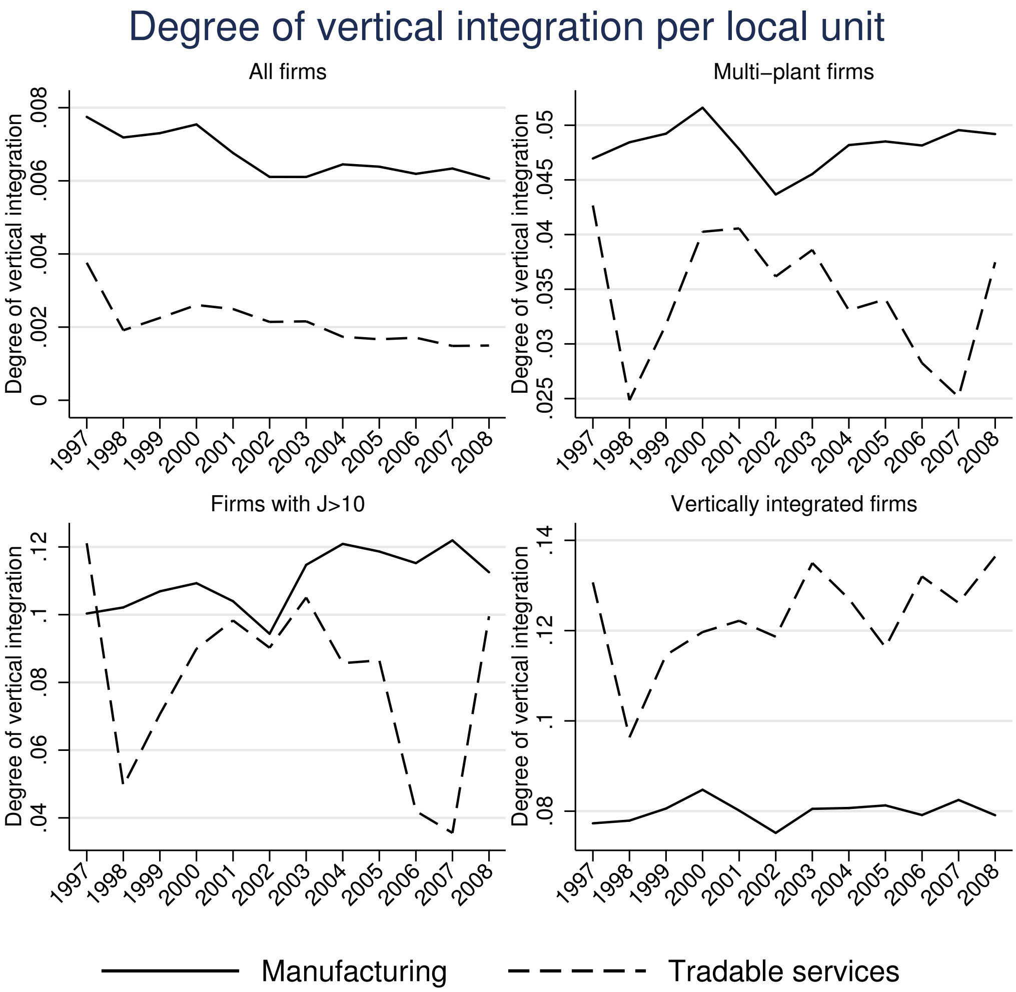

Figure B.3: Degree of vertical integration per local unit according to type of firm

In the tradable service sector the degree of vertical integration for the average local unit is lowest and decreasing over time from 0.37 percent down to 0.15 percent. The multi-plant samples show two significant drops in 1998 and in 2006 – 2007. The large fall in 1998 is a data issue. The measure of vertical integration treats local units of a firm with the same 2-digit but a different 4-digit SIC code as potentially vertically integrated. In 1998 many observations of firms which owned those local units with identical 2-digit, but different 4-digit SIC codes, were confronted with a homogenisation of the activity classification. The former heterogeneous local units are now allocated to the same 4-digit SIC code, therefore former vertically integrated local units are not recognised as those anymore. This problem gets even more severe because some sectors like, for example, the business service sector comprises of plenty of different services which account for the majority of intermediate inputs demanded. If a firm closes one of its service local units, a large absolute drop of the degree of vertical integration can happen. Another fact is that it is very unlikely for a tradable service local unit to be vertically integrated but if they are integrated, then they will be to a higher degree than manufacturing local units.

B.7. The Degree of Vertical Integration Using the Sample Without Top 0.5 Firms

This sample drops the top 0.5 percent of largest firms according to their turnover. If a firm has been once part of the top 0.5 percent it will be dropped for all other years too. This time, the tradable service sector includes also the financial intermediation sector. Figure B.4 shows the average degree of vertical integration for a local unit and figure B.5 for a firm.

The observation of the local unit sample of the year 1998 had to be dropped in the tradable service sector, because of a massive drop in the vertical integration values which was caused by data problems. This can be partly explained with the discussion in section

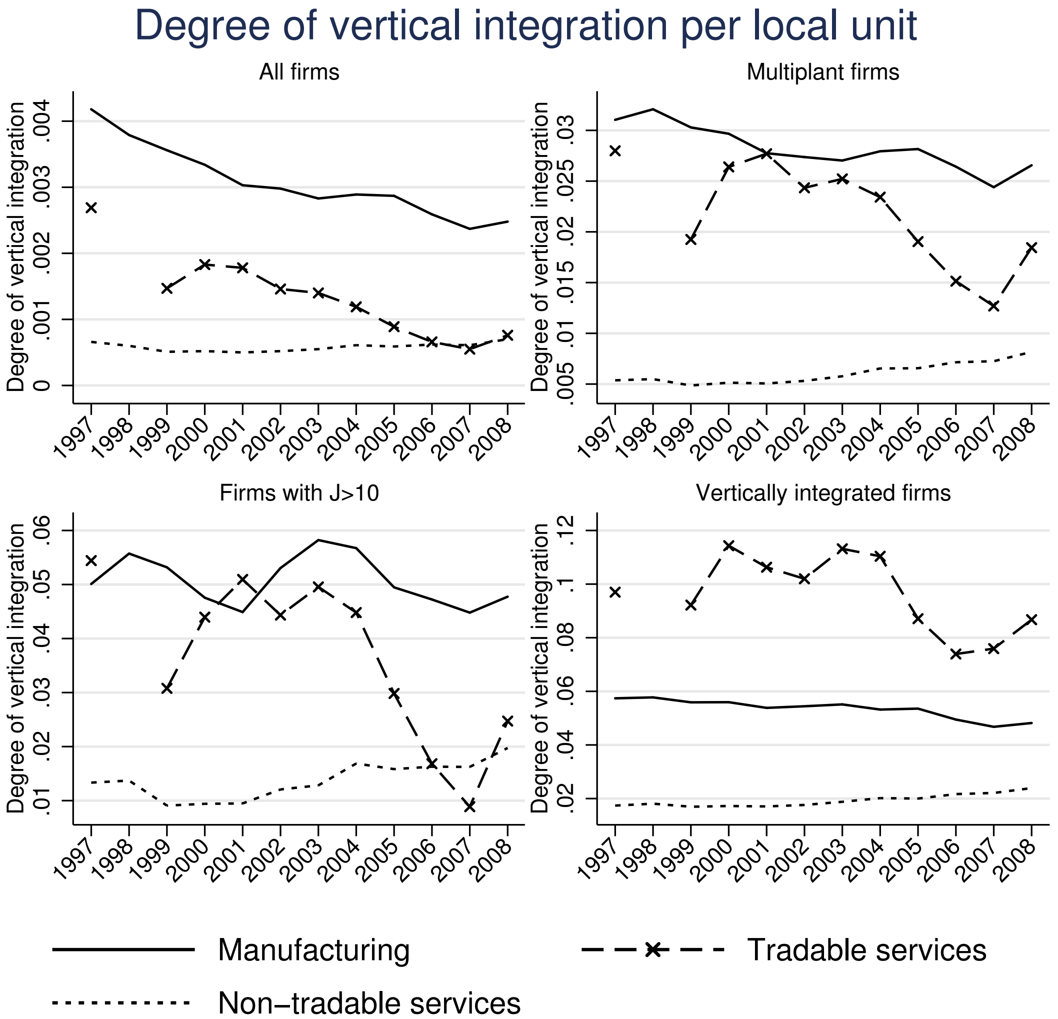

Figure B.4: Degree of vertical integration per local unit according to type of firm, excluding top 0.5

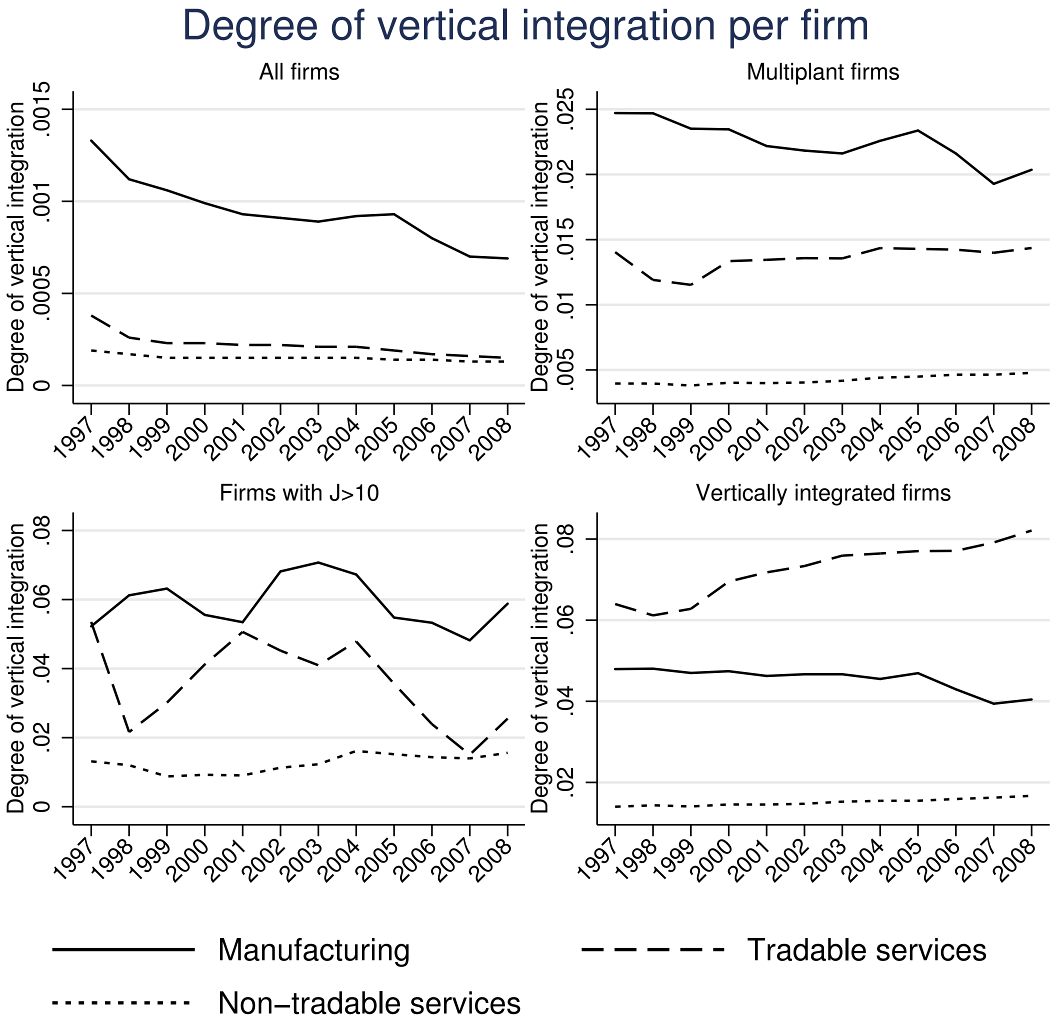

Figure B.5: Degree of vertical integration per firm according to type of firm, excluding top 0.5

4.4.1, that some large firms were confronted with a homogenisation of their 4-digit SIC codes of local units. So even dropping the largest firms of the sample does not mitigate the problem in the tradable service sector.

B.8. Transition Tables

We consider three organisational states:

1. single plant firms,
2. multi-plant firms, not vertically integrated and
3. multi-plant firms, vertically integrated.

It can be the case that some transitions are caused by data inaccuracies. For example, because of a wrong SIC code in one period a firm may appear to change its state from integrated to fragmented, but, after the correct SIC code appears again, changes back to be vertically integrated. To avoid the problem of temporary status changes we will ignore only one period lasting state changes. The cleaned results, calculated using the backward sample, are presented in table B.2. The rows indicate the state of a firm in period t and the columns in period $t+1$. There are two numbers in every cell, the upper one is the absolute number of firms keeping or changing their states and the lower one shows the probability of a firm of a certain state to keep or change to another state. For example, consider the top left panel. We can see that 1,818 single-plant manufacturing firms became vertically integrated. The probability that this event can happen is only 0.14 percent. The tables show the result for the whole twelve year observation period. Firms which appear only once are not included.

The vast majority of firms are keeping its organisational structure. The biggest group is the group of single plant firms staying a single plant firm (more than 99 percent). A similar pattern for both sectors is that it is always more likely for a single-plant firm to

BACKWARD INTEGRATION

	Manufacturing Sector					Tradable Service Sector			
Type	1	2	3	Total	Type	1	2	3	Total
1	1,288,541	2,248	1,818	1,292,607	1	3,710,618	3,802	1,090	3,715,510
	99.69	0.17	0.14	100.00		99.87	0.10	0.03	100.00
2	2,496	26,531	1,177	30,204	2	2,782	52,049	666	55,497
	8.26	87.84	3.90	100.00		5.01	93.79	1.20	100.00
3	2,006	1,395	28,542	31,943	3	734	773	10,598	12,105
	6.28	4.37	89.35	100.00		6.06	6.39	87.55	100.00
Total	1,293,043	30,174	31,537	1,354,754	Total	3,714,134	56,624	12,354	3,783,112
	95.44	2.23	2.33	100.00		98.18	1.50	0.33	100.00

Table B.2: Change of organisational structure over time for clean sample

become a not vertically integrated multi-plant firm than a vertically integrated one.

The main interest lies on how many vertically integrated firms have become fragmented and how many fragmented firms have become vertically integrated. Transition tables cannot show if the degree of vertical integration has increased or decreased but they can give an idea about how many firms changed from one state to another. The discussion will start with the manufacturing sector. The manufacturing sector is the sector for which the number of integrated and not integrated multi-plant firms is quite similar. 1,818 single-plant and 1,177 non vertically integrated multi-plant firms became vertically integrated firms. In contrast to that, 2,006 integrated firms became single-plant or 1,395 non-integrated multi-plant firms. To find out if more firms became fragmented or integrated over time the number of firms becoming integrated (firms turning from a single plant or a not vertically integrated multi-plant firm into an integrated firm) are compared with the number of firms changing their vertically integrated status to a fragmented status. 53.2 percent of all changes are related with backward vertically integrated firms turning into a fragmented state.

In contrast to the manufacturing sector, non-integrated multi-plant firms are far more common in the service sector and the probability of becoming a vertically integrated firm is much lower. Even though the sample is much larger the absolute number of firms changing their status is lower. In the tradable service sector 1,756 (1,090 plus 666) fragmented firms became integrated and 1,507 (734 plus 773) became fragmented. 53.8 percent of all changes are of firms which turned from a fragmented into a backward integrated. To sum it up, in the manufacturing sector more existing firms became fragmented than integrated. This is different to the service sector, where more firms became integrated. Still the absolute number of firms changing the status is extremely low.

The analysis for geographical fragmentation will be conducted in the same manner as above. Again three categories of spatial concentration of firms are used:

1. Concentrated, regional firms, located only in one government office region,
2. spread, bi-regional firms,
3. national firms, located in more than two government office regions.

One criterion for spatial fragmentation is the vertical linkage between the local units of a firm. Therefore only the dispersion of the vertically integrated local units of a firm will be considered, or, to put it differently, how geographically dispersed is the production process of a firm. Therefore I will only keep firms with vertically integrated local units. Horizontally connected local units are ignored. Furthermore, to avoid that a firm exits and re-appears in the sample, because it is temporarily not vertically integrated, I will only keep the firms which do not re-appear. Finally, to get rid of data errors, firms which change their locational status just for one period and switch back to their old one in the next period, are also dropped. We use data based on forward vertically integrated local units to derive the transition tables. Table B.3 reveals the results. The state of the firms in period t are shown in rows and in period $t+1$ in columns. For example, the value of 118 in the table for manufacturing firms states that 118 concentrated firms became bi-regional firms in $t+1$.

In general, the biggest group for all industries is the group of firms with vertically integrated local units in the same region, followed by bi-regional and then national firms. Most firms keep their state. Because only vertically integrated firms are considered, the total number of observation is rather small in comparison to the total firm sample used for organisational fragmentation.

FORWARD INTEGRATION

Manufacturing Sector				
Type	1	2	3	Total
1	13,812	118	29	13,959
	98.95	0.85	0.21	100.00
2	116	4,555	129	4,800
	2.42	94.90	2.69	100.00
3	16	163	3,175	3,354
	0.48	4.86	94.66	100.00
Total	13,944	4,836	3,333	22,113
	63.06	21.87	15.07	100.00

Tradable Service Sector				
Type	1	2	3	Total
1	5,774	47	14	5,835
2	44	2,270	58	2,372
3	-	34	1,461	-
Total	-	2,351	1,533	-

Table B.3: Change of geographical dispersion over time for clean sample

In the manufacturing sector the number of concentrated firms turning into bi-regional firms and vice versa is rather similar. Bi-regional firms become slightly more dispersed then concentrated. The significant change appears because more national firms get less dispersed than firms turning into national acting firms. This causes that the overall number of firms turning into a more concentrated state (295) is higher than of firms becoming more dispersed (276).

The tables for the tradable service sector looks quite basic in comparison to the other sectors. Because less than ten observations appeared in some cells, those values had to be suppressed.[205] The amount of firms with vertically integrated local units is much lower

[205]To be able to publish results the Office for National Statistics demands that statistics with less than ten observations not to be made public, so the identity of a firm cannot be revealed.

in the tradable service sector. In contrast to the manufacturing sector, firms are more likely to become dispersed than concentrated. Slightly more concentrated firms turn into bi-regional firms than vice versa and more bi-regional firms turn into national firms than the other way around.

To sum it up, there are only few firms changing their status between concentrated, bi-regional and national firms. In manufacturing more firms became more concentrated while in the service sector the opposite has happened. Even though the distance between local units and their headquarters increased it seems that it is caused by a higher dispersion of local units within a region or by large firms becoming active in more than 3 regions, which is not captured by the dynamic analysis presented.

C. Explanations for the Organisational Structure of Firms

C.1. Cleaning and Creating Data

C.1.1. BERD

Jones (2007) writes the following about the definition of R&D: "*R&D is defined as* 'creative work undertaken on a systematic basis in order to increase the stock of knowledge, including the knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications'. *This definition is provided by the OECD Frascati Manual .... Guidance notes ... state that 'the guiding line to distinguish R&D activity from non-research activity is the presence or absence of an appreciable element of novelty or innovation. If activity departs from routine and breaks new ground it should be included: if it follows an established pattern it should be excluded'.*"

The extent of the companies included increased from 4,800 in 1995 up to 13,900 in 2005. The peak was reached in 2007 with approximately 20,000 and decreased in 2008 back to the 2006 level of 17,000. Survey data is not available for every year for every firm, therefore those missing observations are imputed by the ONS. As mentioned in the main part of the thesis, some obstacles have to be overcome to be able to merge the BERD with the BSD. Here the procedure will be explained.

In the BERD multiple entries per reporting unit exist and are caused by different locations where R&D is conducted, by civil or defence purposes or by different product groups. I do not differentiate between civil or defence purposes. The BERD applies the UK SIC 92 classification and the BSD UK SIC 03. According to ONS (2002b), page V, the changes between the 1992 and the 2003 version are minor. The adjustments of concern are presented in table C.1. SIC 29.4 was split into three new 4 digit industries and two new industries were added to 74.8 and 72.2.

SIC 92	Agg. Level	SIC 03	New Sectors
29.4	Manufacture of machine tools	29.41	Man. of portable hand held power tools
		29.42	Man. of other metalworking machine tools
		29.43	Man. of other machine tools not elsewhere classified
74.8	Miscellaneous business activities not elsewhere classified	74.86	Call centre activities
72.2	Software consultancy and supply	72.21	Publishing of software

Table C.1: Differences between UK SIC 92 and UK SIC 03

To create a consistent appearance of a firm over time I have aggregated the industries of concern to a more aggregated level. Therefore in manufacturing all new 29.4x are added up to 29.4 again and in the tradable service sector 72.2x to 72.2 and all 74.8x to 74.8.

According to the BERD Quick Guide[206] the data was cleaned by the ONS, but still some adjustments have to be conducted. Besides the data collected through the survey, employment and turnover data is sourced from the Inter Departmental Business Register (IDBR). Some employment and many turnover figures are missing. The data for employment comes from the IDBR and should therefore match with the employment data from the BSD. Unfortunately, that is not always the case. Many observations are included as a lagged variable in the BERD, resulting that the employment/turnover figure of period t is used for $t-1$. The reason might be that the IDBR data is a snapshot of companies in March. In contrast, the BERD is based on a 12 month observation period. Many turnover figures are missing, even though they exist within the BSD and the BSD gets its turnover data from the IDBR again. I will rely on the BSD sample values for employment and turnover to calculate the R&D intensity for specific industries.

[206] Available at `http://www.ons.gov.uk/about/who-we-are/our-services/vml/about-the-vml/datasets-available/dataset-downloads/berd-guides.zip`, accessed on 18/12/10.

The main reference number is the reporting unit reference number, but also enterprise reference numbers (entref) should be provided. The enterprise reference number is crucial for a more detailed analysis of R&D intensity at the firm level. Only from 2003 onwards the ONS started to provide enterprise reference number on a comprehensive scale. Before, only firms which filled in the survey had an enterprise reference number. Being able to link the reporting unit R&D information to enterprises of the BSD allows us to look at the effect of R&D on organisational structure decisions precisely. To merge the BERD with the BSD some prerequisites have to be conducted. Because many enterprise reference numbers are missing I have to impute them, when possible.

Before the imputation can start, a control variable will be created. The reporting unit *postcode* will be crucial for the imputation process. If a postcode gap arose for a reporting unit, then the missing value will be filled in, if the preceding $t-1$ and the following $t+1$ postcode are identical and the industry classification of period t is similar to them of $t-1$ and $t+1$.

The first imputation rule for missing enterprise reference numbers is quite similar to above. If an reporting unit r has a missing enterprise reference number at time t, but an earlier $(t-x)$ and later $(t+y$, where $x, y \in \{1, 10\})$ observation exists, where the $entref^r_{t-x} = entref^r_{t+y}$, all those missing *between* enterprise reference numbers will be imputed with $entref^r_{t-x}$. One requirement is that the postcode of t has not changed. This is illustrated with case I. on the top left hand side of table C.2. Note that all the following tables are made up tables and are not taken from the BERD or BSD. Reporting unit 11 is part of enterprise A in 2003 and 2006, its location is constant, therefore it is assumed that 11 is also part of A in 2004 and 2005. The upper right corner, case II., of the table illustrates the case, when no imputation will happen. The enterprise number is different in 2003 and 2006.

The method seems to work for most missing enterprise reference numbers after 2002 but

Case	I.				II.			
Before	**ruref**	**year**	**entref**	**poco berd**	**ruref**	**year**	**entref**	**poco berd**
Imputation	11	2003	A	NG9	11	2003	B	NG9
	11	2004	.	NG9	11	2004	.	NG9
	11	2005	.	NG9	11	2005	.	NG9
	11	2006	A	NG9	11	2006	A	NG9
After	**ruref**	**year**	**entref**	**poco berd**	**ruref**	**year**	**entref**	**poco berd**
Imputation	11	2003	A	NG9	11	2003	B	NG9
	11	2004	**A**	NG9	11	2004	.	NG9
	11	2005	**A**	NG9	11	2005	.	NG9
	11	2006	A	NG9	11	2006	A	NG9
Case	**III.**				**IV.**			
Before	**ruref**	**year**	**entref**	**poco berd**	**ruref**	**year**	**entref**	**poco berd**
Imputation	11	2000	.	NG9	11	2003	.	S1
	11	2001	.	NG9	11	2004	.	S1
	11	2002	.	NG9	11	2005	.	S1
	11	2003	A	NG9	11	2006	A	NG9
After	**ruref**	**year**	**entref**	**poco berd**	**ruref**	**year**	**entref**	**poco berd**
Imputation	11	2000	**A**	NG9	11	2000	.	S1
	11	2001	**A**	NG9	11	2001	.	S1
	11	2002	**A**	NG9	11	2002	.	S1
	11	2003	A	NG9	11	2003	A	NG9

Table C.2: BERD enterprise reference number imputation rules I

is rather poor for earlier years. For earlier missing observations I will impute $entref_t^r = entref_{t+1}^r$, but only if the reporting unit has not experienced any ownership change and the postcode is still the same. This is illustrated at the bottom part of table C.2, case III. All missing enterprise reference number for reporting unit 11 will be imputed. Taking account of the ownership change is important, otherwise it could be the case that the missing values of case B will be imputed. It is impossible to evaluate if enterprise reference number A or B is the correct one. How can we make sure that the imputed enterprise reference numbers are correct? The postcodes of the BSD can help. A reporting unit can be any local unit of an enterprise. The BSD contains exactly that information, if the reporting unit postcode is identical to the local unit postcode from the BSD, it is very likely that the reporting unit is part of the enterprise.

Again, certain rules have to be applied. The first rule drops all BERD reporting units if a specific enterprise reference number of a certain year does not exist in the BSD. This is illustrated with reporting unit 11 in table C.3.

Sometimes a BERD enterprise reference number and year combination does exist, but the postcodes are different. If it has ever been the case, that a reporting unit had at least once a postcode in the BERD, which is identical to a postcode in the BSD, then all observations will be kept. Reporting unit 12 has a misspecified postcode in 2000 and 2001. Because it has the right postcode in 2003, I will keep all observations. Reasons for this misspecification are that the BERD data is partly gained from different sources than the BSD. Therefore the postcode can differ slightly. It is worth noting that after merging with the BSD no reporting unit exists, which changes its enterprise reference number over time any more.

If the reporting unit has never had a postcode identical to the enterprise it was assumed to be belonged to, then the reporting unit will be dropped. This is shown by reporting unit 13 in table C.3.

Before	**ruref**	**year**	**entref berd**	**entref bsd**	**poco berd**	**poco bsd**
Cleaning	11	2000	A	–	NG9	–
	11	2001	A	A	NG9	NG9
	11	2002	A	A	NG9	NG9
	12	2000	A	A	XX	S1
	12	2001	A	A	XX	S1
	12	2002	A	A	S1	S1
	13	2000	A	A	D3	ST7
	13	2001	A	A	D3	ST7
	13	2002	A	A	D3	ST7
After	**ruref**	**year**	**entref berd**	**entref bsd**	**poco berd**	**poco bsd**
Cleaning	11	2001	A	A	NG9	NG9
	11	2002	A	A	NG9	NG9
	12	2000	A	A	XX	S1
	12	2001	A	A	XX	S1
	12	2002	A	A	S1	S1

Table C.3: BERD enterprise reference number imputation rules II

Finally, an enterprise can have more than one reporting unit. If that is the case all values are added up and collapsed to one observation.

C.1.2. ASHE

Skill intensity information of ASHE

The information on the skill level of employees needs further explanations. The classification between highly skilled and unskilled workers is based on Her Majesty's Stationery Office (2000), whereby the Standard Occupational Classification (SOC) is used to allocate Jobs to four different skill levels. Level one indicates the lowest skilled workers, like elementary trade occupations and level four high skilled workers, like research professionals.[207] The exact job allocation is captured in table C.5 on page 290. Until 2001 SOC 1990 was employed, from 2002 onwards it was changed to SOC 2000. SOC 1990 and SOC 2000 are not comparable.[208] The differentiation between low and high skilled wages requires splitting the sample into two halves, one for the period 1998 – 2001 and the other one from 2002 – 2008.

Cleaning the ASHE

Two cleaning strategies were employed: *Firstly*, many duplicates exist in ASHE, especially in the years 2004 and 2006, where it seems that every observation was included twice. Duplicates were dropped. If it was just a miscoding, for example the same ID number was entered for two different observations, then they were still kept, because the interest does not lie on following an individuals over time. Observations with missing ID numbers were only dropped when an identical entry exists, unique ones were kept. *Secondly*, the postcodes in 1997 are miscoded. Out of 150,000 observations, 90,000 postcodes could not be found in the National Statistics Postcode Directory of 2009. This was caused by wrong data input. For approximately 80,000 observation a 0 was added to the

[207] According to the ONS skill levels *"... are approximated by the length of time deemed necessary for a person to become fully competent in the performance of the tasks associated with a job."* (Her Majesty's Stationery Office, 2000, p. 5). For example, for the first skill level only compulsory eduction is required. For the fourth skill level a degree and work experience are necessary.

[208] The VML offers some look-up tables to connect SOC 1990 with SOC 2000, but as explained in ONS (2009a), it is not recommended to use SOC 2000 before 2002. An Excel file on the VML server reveals the complexity of allocating SOC 1990 to SOC 2000 and vice versa.

end of the postcode. Deleting this wrong number reduces the non-matchable observations to 18,000. This remainder was caused by a non-systematically wrong data input. Table C.5 shows the skill level of different occupations.

SIC	Description
15.41	Manufacture of crude oils and fats
15.43	Manufacture of margarine and similar edible fats
15.62	Manufacture of starches and starch products
15.88	Manufacture of homogenised food preparations and dietetic food
15.92	Production of ethyl alcohol from fermented materials
15.93	Manufacture of wines
15.95	Manufacture of other non-distilled fermented beverages
17.14	Preparation and spinning of flax-type fibres
17.15	Throwing and preparation of silk including from noils and throwing and texturing of synthetic or artificial filament yarns
17.16	Manufacture of sewing threads
17.17	Preparation and spinning of other textile fibres
17.25	Other textile weaving
18.10	Manufacture of leather clothes
18.30	Dressing and dyeing of fur; manufacture of articles of fur
20.52	Manufacture of articles of cork, straw and plaiting materials
21.11	Manufacture of pulp
23.10	Manufacture of coke oven products
24.11	Manufacture of industrial gases
25.12	Retreading and rebuilding of rubber tyres
26.25	Manufacture of other ceramic products
26.53	Manufacture of plaster
26.65	Manufacture of fibre cement
27.31	Cold drawing
27.32	Cold rolling of narrow strip
27.35	This code is no longer in use
52.73	Repair of watches, clocks and jewellery
55.11	?
55.12	?
71.23	Renting of air transport equipment

Table C.4: List and description of BSD SIC which cannot be matched with ASHE

	SOC2000		SOC1990	
Level 4	11	Corporate managers	1a	Corporate managers and administrators
	21	Science and technology professionals	2a	Science and engineering professionals
	22	Health professionals	2b	Health professionals
	23	Teaching and research professionals	2c	Teaching professionals
	24	Business and public service professional	2d	Other professional occupations
Level 3	12	Managers and proprietors in agriculture and services	1b	Managers/proprietors in agriculture and services
	31	Science and technology associate professionals	3a	Science and engineering associate professionals
	32	Health and social welfare associate professionals	3b	Health associate professionals
	33	Protective service occupations	6a	Protective service occupations
	34	Culture, media and sports occupations	3c	Other associate professional occupations
	35	Business and public service associate professionals	7a	Buyers, brokers and sales representatives
	51	Skilled agricultural trades	9a	Other occupations in agriculture, forestry and fishing
	52	Skilled metal and electrical trades	5b	Skilled engineering trades
	53	Skilled construction and building trades	5a	Skilled construction trades
	54	Textiles, printing and other skilled trade	5c	Other skilled trades
Level 2	41	Administrative occupations	4a	Clerical occupations
	42	Secretarial and related occupations	4b	Secretarial occupations
	61	Caring personal service occupations	6b	Personal service occupations
	62	Leisure and other personal service occupation		
	71	Sales occupations	7b	Other sales occupations
	72	Customer service occupations		
	81	Process, plant and machine operatives	8a	Industrial plant and machine operators, assemblers
	82	Transport and mobile machine drivers and operatives	8b	Drivers and mobile machine operators
Level 1	91	Elementary trades, plant and storage related occupations	9b	Other elementary occupations
	92	Elementary administration and service occupations		

Table C.5: Categorisation of job skill levels according to SOC 1990 and SOC 2000, based on Her Majesty's Stationery Office (2000).

C.2. The Creation of the Capital Stock Measures

Because the ARD does not select the same firms every year, gaps appear. Employment and capital expenditure data is crucial for the calculation of the capital stock and therefore those gaps will be filled in. The second challenge is the calculation of the capital stock in the first year of a firm appearing in the data set. Appearing the first time in the ARD does not imply that it has not existed before. The first year capital stock is calculated by using the Volume in Capital Services (VICS).

The structure is as follows:

1. Preparing the data sets, including data imputations.
2. Finding capital stock for the first year of appearance in the ARD.
3. Using a Perpetual Inventory Model (PIM).

Preparing the data: Data is available for nearly the whole necessary observation period from 1997 – 2006.[209] The `dat` files of the ARD are used including firms which have been selected and returned the survey sheets. Firms are not always selected or return the sheets every year, therefore gaps can appear. To fill this gaps another data set called the ARD Register Panel is used. Firms which have never been selected are dropped and then the ARD and the ARD Register Panel are merged. The merge leads to many missing values which have to be imputed. Gilhooly (2009) describes the imputation methods in detail, so here is only a brief summary. First, employment figures have to be imputed, because they will be needed for further imputations. If there is a gap in the employment data, then just the average of the leading and the following employment will be derived. If the missing employment data is at the beginning (end) of the appearance of the firm, then the three year average of the following (preceding) years will be taken. The calculation of

[209] Data for 2007 and 2008 are also available, but unfortunately there are some serious issues with those years and only 2,000 out of 47,000 observations can be used.

the capital stock requires the capital expenditure of firms. Therefore all missing values have to be imputed again. Because of the volatile behaviour of capital expenditure, Gilhooly (2009) recommends to calculate an average capital stock per employee and then to impute the missing capital expenditure values by multiplying the averages with the actual number of employees.

Finding first year capital stocks: A problem of the calculation of the capital stock is to find the capital stock for the first year of appearance of a firm. Just because a firm appears the first time in the ARD does not necessarily imply that it is actually the first year of existence. The main idea is to use aggregate investment capital from the Volume in Capital Services (VICS) and allocate those capital stocks to the ARD firms. The number of firms included is much smaller than the population size, therefore we have to find first the share of the industry capital which we can allocate to the ARD firms. Because we do not have capital stock data for the ARD firms, we approximate the share by using the share of investment of ARD firms in comparison to total investment (equation C.1). Then we multiply the share with the aggregated capital stock data from the VICS (equation C.2) and get the capital we can allocate to the ARD firms.

$$Firm\ Investment\ Share_{(asset)} = \frac{\overbrace{\sum (rncapex)_{year,\,sic,\,asset}}^{\text{ARD}}}{\underbrace{Industry\ Investment_{year,\,sic,\,asset}}_{\text{VICS}}} \tag{C.1}$$

$$Alloc.\ Firm\ Capital_{(asset)} = \underbrace{Industry\ Capital_{asset}}_{VICS} \times Firm\ Inv.\ Share_{(asset)} \tag{C.2}$$

Now the capital has to be allocated to the ARD firms. A variable is needed which is highly correlated with the capital stock of a firm and which has been collected for most of the periods. This variable is total purchases. As presented in equation C.3 a mixture of total purchases and employment has been used to calculate the share of the aggregated capital stock which has to be allocated as precise as possible.[210]

$$m\_Share = \left(\frac{totpurch}{\sum totpurch_{sic3d\,year}}\right) \times \left(\frac{\sum employment_{sic3d\,year}}{\sum employment_{siclett\,year}}\right) \tag{C.3}$$

Perpetual Inventory Model: The PIM adds the capital expenditures of the firm to the existing capital stock annually, taking account of depreciations rates. Those are twenty percent for vehicles, six percent for plant & machinery and two percent for building. The first year capital stock is calculated as the allocated capital from the VICS plus the real capital expenditures of the firm in the first year:

$$Firm\,Cap.\,Stock_{asset\,t=1} = (Alloc.\,Firm\,Capital_{asset} \times m\_Share) + rncapex_{t=1} \tag{C.4}$$

In the following year the new capital expenditures are added and the depreciation is deducted:

$$Firm\,Cap.\,Stock_{asset\,t+1} = (Alloc.\,Firm\,Cap._{asset\,t} \times (1-\delta)_{asset}) + rncapex_{t+1} \tag{C.5}$$

where δ stands for the depreciations rate. Finally to get the total capital stock of a firm in year t, all three kind of assets are aggregated:

$$Firm\ Total\ Cap.\ Stock_{year} = \sum Firm\ Cap.\ Stock_{asset} \tag{C.6}$$

It can be the case that the allocated capital stock in the first year is too low, therefore negative capital stocks of a firm arise during the observation period. This problem is solved by adding exactly the absolute of the negative value to all observations of a reporting unit. This procedure has been conducted several times to minimise the amount of negative capital stocks.

[210]The VICS contains information at the industry letter level, therefore by using employment we can distribute the capital to a more disaggregated level.

C.3. Empirical Results

C.3.1. Stage 1: Robustness checks

Variables	OLS lag		PRO lag		OLS curr		PRO curr		FIX curr	
Manufacturing										
Hetero.	-0.0002		-0.0103		0.0003		-0.0053		-0.0008	*
Frontier	0.0004	*	0.0005		-0.0007	***	-0.0432	***	0.0007	***
Age^2									0.0001	***
Employment	-0.0384	***	0.3834	***	-0.0392	***	0.3914	***	-0.0315	***
$Employment^2$	0.0206	***	0.0292	***	0.0206	***	0.0294	***	0.0190	***
Foreign	0.0153	***	0.0161		0.0174	***	0.0447	***	0.0117	***
Herfindahl	-0.0108	*	-0.1266		-0.0040		-0.1033		0.0009	
Ind. Wage	-0.0008		-0.0235		-0.0007		-0.0157		0.0046	***
Reg. Wage	0.0052	**	0.0986	**	0.0045	**	0.1116	***	0.0002	
Agglomeration	0.0004		0.0094	**	0.0002		0.0104	**	-0.0000	
Ex. R&D	0.0354		0.4284		0.0041		-0.1040		-0.0226	
Ih. R&D	-0.0194		-0.2021		-0.0021		0.0692		0.0139	
Unionisation	0.0027		-0.1503	***	0.0041	*	-0.1578	***	0.0005	
Constant	0.0025		-3.3470	***	-0.0058		-3.7959	***	-0.0269	*
Observations	1,009,570		1,008,547		1,263,414		1,263,078		1,263,414	
R-Square	.262				.264				.0489	
Tradable Services										
Hetero.	0.0064	***	0.2045	***	0.0075	***	0.1918	***	0.0004	
Frontier	0.0018	***	0.0488	***	0.0014	***	0.0210	***	0.0010	***
Age^2									0.0000	***
Employment	-0.0160	***	0.5944	***	-0.0161	***	0.6185	***	-0.0081	***
$Employment^2$	0.0179	***	-0.0033		0.0168	***	-0.0093	***	0.0086	***
Foreign	0.0047	***	0.1335	***	0.0066	***	0.1842	***	0.0103	***
Herfindahl	-0.0422	***	-2.5247	***	-0.0690	***	-3.7631	***	0.0158	**
Ind. Wage	0.0138	***	0.5416	***	0.0147	***	1.0542	***	0.0026	***
Reg. Wage	-0.0106	***	-0.1118	**	-0.0096	***	-0.0385		0.0010	
Agglomeration	0.0005	***	0.0053		0.0007	***	0.0115	**	-0.0000	
Ex. R&D	-0.0228		-1.9355	**	-0.0171		-2.0485	***	0.0259	***
Ih. R&D	0.0008		0.5062	*	-0.0070		0.5200		-0.0082	**
Unionisation	-0.0008		0.2233		-0.0082	***	-0.0919		-0.0103	***
Constant	-0.0383	***	-6.2139	***	-0.0421	***	-10.1161	***	-0.0174	**
Observations	933,263		933,153		1,259,273		1,259,045		1,259,273	
R-Square	.201				.194				.0259	
Firm FE	No		No		No		No		Yes	
Time FE	Yes		Yes		Yes		Yes		Yes	
Industry FE	Yes		Yes		Yes		Yes		No	
Region FE	Yes		Yes		Yes		Yes		No	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table C.6: Current and lagged OLS, Probit and FE estimation results for stage 1

	Manufacturing						Tradable Services					
Variables	Hetero. 3		C4		Sci. Emp.		Hetero. 3		C4		Sci. Emp.	
Hetero.			-0.0011	**	-0.0012	**			0.0009	**	0.0009	**
Hetero. 3	-0.0123	***					-0.0013					
Frontier	0.0018	***	0.0021	***	0.0021	***	0.0015	***	0.0015	***	0.0015	***
Age^2	0.0000	***	0.0000	***	0.0000	***	0.0000	***	0.0000	***	0.0000	***
Employment	-0.0195	***	-0.0216	***	-0.0216	***	-0.0067	***	-0.0073	***	-0.0073	***
$Employment^2$	0.0127	***	0.0138	***	0.0138	***	0.0079	***	0.0085	***	0.0085	***
Foreign	0.0012		0.0027	*	0.0028	*	0.0059	***	0.0092	***	0.0092	***
Herfindahl	0.0107	***			0.0091	**	0.0099				0.0199	**
C4			0.0033						0.0054	**		
Ind. Wage	0.0022		0.0030	*	0.0031	*	0.0036	**	0.0027	**	0.0030	**
Reg. Wage	0.0012		0.0009		0.0009		-0.0007		-0.0007		-0.0007	
Agglomeration	0.0001		0.0000		0.0000		-0.0000		-0.0001		-0.0001	
Ex. R&D	0.0133		0.0174		0.0079		0.0370	**	0.0306	**	0.0397	***
Ih. R&D	-0.0025		-0.0054				-0.0117	**	-0.0083	*		
Sci. Emp.					0.0009						-0.0131	**
Unionisation	-0.0023		-0.0016		-0.0017		-0.0087	***	-0.0118	***	-0.0121	***
Constant	0.0018		-0.0112		-0.0112		-0.0081		-0.0051		-0.0066	
Observations	890,156		1,009,570		1,009,570		844,888		933,263		933,263	
R-Square	.0207		.0255		.0255		.02		.0235		.0235	
Firm FE	Yes		Yes		Yes		Yes		Yes		Yes	
Time FE	Yes		Yes		Yes		Yes		Yes		Yes	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table C.7: Robustness checks for stage 1

C.3.2. Stage 2: Robustness checks

While in the manufacturing sector the significance and sometimes even the signs differ from each other, the coefficients in the tradable service sector are completely different for competition and industry wage variables.

					Manufacturing					
Variables	OLS lag		PRO lag		OLS curr		PRO curr		FIX curr	
Hetero.	-0.0085		-0.0379		0.0047		0.0028		0.0039	
Frontier	-0.0237	***	-0.0807	***	-0.0346	***	-0.1216	***	-0.0034	
age	0.0030	***	0.0098	***	0.0041	***	0.0134	***		
Age^2									0.0001	***
Employment	-0.0281	***	-0.0266		-0.0256	***	-0.0026		0.0406	***
Employment^2	0.0129	***	0.0323	***	0.0131	***	0.0316	***	0.0181	***
Foreign	-0.0103		-0.0344	*	-0.0067		-0.0220		0.0060	
Herfindahl	0.0267		0.1030		0.0055		0.0213		0.0236	
Ind. Wage	-0.0069		-0.0359		0.0102		0.0208		0.0216	
Agglomeration	0.0046	*	0.0144	*	0.0039		0.0123		-0.0023	
Ex. R&D	0.3071		0.9023		0.0050		0.0369		0.0082	
Ih. R&D	-0.1910		-0.5585		-0.0323		-0.0991		-0.0767	
Unionisation	-0.0579	**	-0.2186	**	-0.0447	*	-0.1880	**	-0.0017	
Constant	0.1666		-0.8329		0.0282		-1.5238	***	-0.3629	***
Observations	65,446		65,323		76,766		76,692		76,766	
R-Square	.121				.131				.0684	
					Tradable Services					
Hetero.	-0.0316	***	-0.0871	**	-0.0270	***	-0.0985	**	-0.0144	***
Frontier	0.0050	***	0.0188	**	0.0011		-0.0015		0.0027	*
age	0.0009	***	0.0064	***	0.0016	***	0.0112	***		
Age^2									0.0001	***
Employment	-0.0064	**	0.0343	**	-0.0072	***	0.0450	***	0.0325	***
Employment^2	0.0050	***	0.0151	***	0.0050	***	0.0139	***	0.0015	**
Foreign	0.0238	***	0.0533	*	0.0307	***	0.0846	***	0.0112	*
Herfindahl	0.3768	***	-0.0235		0.5955	***	0.6423		0.3201	***
Ind. Wage	-0.0306		0.1522		-0.2116	***	-0.6109	***	-0.1604	***
Agglomeration	-0.0030	***	-0.0176	***	-0.0036	***	-0.0214	***	-0.0019	*
Ex. R&D	0.2824	*	-0.4282		0.3101	***	-0.1312		0.1774	**
Ih. R&D	-0.1245	**	0.0456		-0.1213	*	0.1244		0.0685	*
Unionisation	0.1091	***	0.4626	**	0.0585		0.3159		0.0429	*
Constant	0.2722	*	-2.3585	***	1.3790	***	2.3781	**	0.9491	***
Observations	66,470		66,171		79,361		78,912		79,361	
R-Square	.0853				.0892				.038	
Firm FE	No		No		No		No		Yes	
Time FE	Yes		Yes		Yes		Yes		Yes	
Industry FE	Yes		Yes		Yes		Yes		No	
Region FE	Yes		Yes		Yes		Yes		No	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table C.8: Current and lagged OLS, Probit and FE estimation results for stage 2

The problem of the wage measure is that just a high wage in an industry might not reflect that the wage of low skilled workers is necessarily higher in those sectors. Therefore Girma and Görg (2004) differentiate between wages of skilled and unskilled labour. Because of a change in the SOC the sample is split into two parts, one using SOC 1990 for the years 1998 – 2001 and another one using SOC 2000 for the years 2002 – 2008. Results are presented in tables C.9 – C.10 in the last two bottom columns. We find a negative but insignificant relationship between low skilled industry wages and vertical integration using SOC 1990 in manufacturing and in the tradable service sector. The SOC 2003 is only significantly negative for high-skilled wages in the tradable service sector. Concluding, we cannot find a clear evidence for Girma and Görg's cost-savings argument.

The other columns in tables C.9 – C.10 test the results if alternative covariates were considered. The *base* column shows the baseline results and the *Hetero.* column the results if the heterogeneity measure based on all firms was used. In the *Hetero. 3* columns we present the results for the heterogeneity measure based on a three year average productivity growth. In the *C4* column the Herfindahl index was substituted with the C4 concentration index. The coefficients always keep the same size, but are only significant in the tradable service sector. To check if the in-house R&D measure is reliable, a scientific staff to total employment ratio for every industry was calculated. The results are presented in the *Scientist* column. While there is no change in the non-R&D variables, the effect of external R&D is smaller in manufacturing, but positive, and the scientific employment ratio is still negative. In the tradable service sector the size of the external R&D coefficient becomes significant and larger, but now the sign of the scientific staff variable is negative. Finally, instead of using the 99^{th} percentile firm as technological leader of an industry, the most productive firm was employed. Results are part of column *Frontier*, robust and hardly change in any sector.

Manufacturing					
Variables	Base	Hetero.	Hetero. 3	Inter.	C4
Hetero.	-0.0111			-0.0110	-0.0114
Base Hetero.		-0.0212 *			
3y. av. Het.			-0.0398		
Frontier	0.0070 **	0.0084 ***	0.0057 *	0.0071 **	0.0070 **
Age^2	-0.0000 *	-0.0000	-0.0001 **	-0.0000 *	-0.0000 *
Employment	0.0466 ***	0.1210 ***	0.0479 ***	0.0467 ***	0.0466 ***
$Employment^2$	0.0108 ***		0.0098 ***	0.0108 ***	0.0108 ***
Foreign	0.0013	0.0014	0.0020	-0.0107	0.0013
Foreign×ex. R&D				0.1291	
Foreign×ih. R&D				0.0519	
Foreign×Union				0.0241	
Herfindahl	0.0534	0.0528	0.0533	0.0541	
C4					0.0344
Ind. Wage	0.0102	0.0079	0.0027	0.0106	0.0078
Agglomeration	-0.0002	-0.0001	-0.0001	-0.0002	-0.0002
Ex. R&D	0.3236 *	0.3094	0.2808	0.3200	0.3417 *
Ih. R&D	-0.2390 *	-0.2365 *	-0.2333 *	-0.2943 **	-0.2505 **
Unionisation	-0.0304 *	-0.0318 *	-0.0300	-0.0346 *	-0.0322 *
Constant	-0.0578	-0.1474	0.0199	-0.0577	-0.0495
Observations	65,446	65,448	58,882	65,446	65,446
R-Square	.037	.0351	.0311	.0371	.037

Variables	Sci. Emp.	Front. max	SOC90	SOC03
Hetero.	-0.0110	-0.0113	0.0065	-0.0252 **
Frontier	0.0071 **		0.0038	0.0065 *
max. Frontier		0.0035 *		
Age^2	-0.0000 *	-0.0000 *	-0.0000	-0.0001 **
Employment	0.0465 ***	0.0440 ***	-0.0038	0.0450 ***
$Employment^2$	0.0108 ***	0.0109 ***	0.0061 **	0.0083 ***
Foreign	0.0011	0.0015	0.0101	-0.0026
Herfindahl	0.0584	0.0498	0.0636	-0.0017
Ind. Wage	0.0081	0.0080		
LS wage 90			-0.0167	
HS wage 90			0.0013	
LS wage 03				0.0237 *
HS wage 03				0.0072
Agglomeration	-0.0002	-0.0001	0.0004	-0.0020
Ex. R&D	-0.0222	0.3298 *	1.8808	0.4457 *
Ih. R&D		-0.2445 **	-0.4137	-0.4261 **
Sci. staff	-0.0264			
Unionisation	-0.0307 *	-0.0322 *	-0.0443	-0.0071
Constant	-0.0469	-0.0347	0.2638 *	-0.0947
Observations	65,446	65,446	18,415	44,626
R-Square	.0369	.037	.00577	.0202
Firm FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table C.9: Robustness checks for manufacturing sector in stage 2

Tradable Services					
Variables	Base	Hetero.	Hetero. 3	Inter.	C4
Hetero.	-0.0162 ***			-0.0164 ***	-0.0168 ***
Base Hetero.		0.0146 **			
3y. av. Het.			0.0954 ***		
Frontier	0.0046 **	0.0050 ***	0.0051 **	0.0046 **	0.0047 **
Age^2	0.0000	0.0000	0.0000	0.0000	0.0000
Employment	0.0385 ***	0.0356 ***	0.0455 ***	0.0383 ***	0.0386 ***
Employment^2	-0.0005		-0.0015 *	-0.0005	-0.0005
Foreign	0.0007	0.0009	0.0013	-0.0128	0.0010
Foreign×ex. R&D				0.2864	
Foreign×ih. R&D				-0.1217	
Foreign×Union				0.0821	
Herfindahl	0.3407 ***	0.3803 ***	0.3560 ***	0.3440 ***	
C4					0.0529 *
Ind. Wage	-0.0981 ***	-0.0988 ***	-0.1052 ***	-0.0990 ***	-0.0935 ***
Agglomeration	-0.0026 *	-0.0026 *	-0.0022 *	-0.0026 *	-0.0026 *
Ex. R&D	0.1117	0.0859	0.0212	0.0778	0.0455
Ih. R&D	0.0684 *	0.0697 *	0.0871 *	0.0851 *	0.0869 *
Unionisation	0.0425	0.0340	0.0130	0.0346	0.0472 *
Constant	0.6362 ***	0.6166 ***	0.5958 ***	0.6432 ***	0.6053 ***
Observations	66,470	66,470	60,989	66,470	66,470
R-Square	.0263	.0261	.0226	.0264	.0261
Variables	Sci. Emp.	Front. max	SOC90	SOC03	
Hetero.	-0.0165 ***	-0.0177 ***	-0.0030	-0.0150 **	
Frontier	0.0045 **		0.0044	0.0060 **	
max. Frontier		0.0042 ***			
Age^2	0.0000	0.0000	-0.0002 ***	0.0000 *	
Employment	0.0386 ***	0.0379 ***	-0.0202 *	0.0497 ***	
Employment^2	-0.0005	-0.0004	0.0060 ***	-0.0022 **	
Foreign	0.0005	0.0010	0.0365 *	0.0101	
Herfindahl	0.3813 ***	0.3489 ***	0.1221	0.1427	
Ind. Wage	-0.0977 ***	-0.0997 ***			
LS wage 90			-0.0097		
HS wage 90			0.1089 **		
LS wage 03				0.0186	
HS wage 03				-0.0785 ***	
Agglomeration	-0.0026 *	-0.0026 *	-0.0053 *	-0.0022	
Ex. R&D	0.2793 **	0.1117	-0.0852	-0.1783	
Ih. R&D		0.0606	0.1489	0.1478 **	
Sci. staff	-0.0011				
Unionisation	0.0485 *	0.0298	-0.0607	-0.0373	
Constant	0.6331 ***	0.6719 ***	-0.5084	0.4265 **	
Observations	66,470	66,470	16,498	49,200	
R-Square	.0263	.0266	.0153	.0126	
Firm FE	Yes	Yes	Yes	Yes	
Time FE	Yes	Yes	Yes	Yes	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table C.10: Robustness checks for the tradable service sector in stage 2

C.3.3. Stage 3: Robustness checks

	Manufacturing			Tradable Services		
Variables	OLS lag	OLS curr	FIX curr	OLS lag	OLS curr	FIX curr
Hetero.	-180	523	980	-3,456 ***	-3,328 ***	-2,259 ***
Frontier	1,712 ***	843 **	-266	2,237 ***	1,708 ***	719 ***
Age^2			17 ***			7 ***
Emp.	-10,004 ***	-10,558 ***	-10,408 ***	-2,039 ***	-2,481 ***	743
Emp.^{2}	3,030 ***	3,144 ***	3,665 ***	1,196 ***	1,218 ***	514 ***
Foreign	9,241 ***	8,862 ***	-45	7,523 ***	8,334 ***	1,648
Herfindahl	4,012	8,730	2,949	48,551 **	61,354 ***	28,254 *
Ind. Wage	2,532	6,347	4,142 *	-1,057	-15,935 ***	-12,089 ***
Agglom.	-325	-208	872 **	-300 *	-200	-286
Ex. R&D	59,755	32,826	-38,193	-16,060	12,069	14,720
Ih. R&D	-30,935	-15,103	17,966	904	-14,274	9,774 *
Unionisation	-4,759	-7,385 *	-5,037 *	10,575 *	8,913	14,882 ***
Constant	-45,001	-68,930 *	6,645	12,355	109,391 ***	101,140 ***
Observations	65,446	76,766	76,766	66,470	79,361	79,361
R-Square	.172	.174	.0309	.081	.0824	.0163
Firm FE	No	No	Yes	No	No	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	No	Yes	Yes	No
Region FE	Yes	Yes	No	Yes	Yes	No

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table C.11: Current and lagged OLS, Probit and FE estimation results for stage 3

Variables	Base FIX		C4		Sci. Emp.		Frontier		Hetero. 3	
Manufacturing										
Hetero.	-335		-337		-281		-383			
3y. av. Het.									111	
Frontier	1,047	**	1,047	**	1,062	**			725	
max. Frontier							347			
Age^2	9	***	9	***	9	***	9	***	8	**
Employment	-4,659	***	-4,659	***	-4,659	***	-5,172	***	-5,360	***
$Employment^2$	2,302	***	2,302	***	2,301	***	2,324	***	2,321	***
Foreign	-1,026		-1,026		-1,027		-996		-1,785	
Herfindahl	1,992				2,446		1,578		3,038	
C4			1,006							
Ind. Wage	-422		-483		-60		-741		-1,804	
Agglomeration	339		340		339		355		75	
Ex. R&D	-18,999		-18,364		7,215		-18,272		-27,846	
Ih. R&D	4,490		4,090				3,749		8,737	
Sci. staff					-12,460					
Unionisation	-4,066		-4,094		-4,176		-4,256		-5,375	*
Constant	26,859		27,027		25,126		29,595		32,205	
Observations	65,446		65,446		65,446		65,446		58,882	
R-Square	.0146		.0146		.0147		.0145		.0128	
Tradable Services										
Hetero.	-1,993	**	-2,054	**	-2,005	**	-2,270	***		
3y. av. Het.									10,753	**
Frontier	1,153	***	1,168	***	1,148	***			1,041	***
max. Frontier							837	***		
Age^2	2		2		2		1		1	
Employment	2,659	***	2,674	***	2,671	***	2,376	***	3,125	***
$Employment^2$	178		179	*	175		193	*	84	
Foreign	-275		-244		-307		-179		34	
Herfindahl	37,311	**			40,319	**	39,592	**	35,645	*
C4			6,191							
Ind. Wage	-6,385	**	-5,908	**	-6,436	**	-6,772	**	-9,040	***
Agglomeration	-459	**	-458	**	-457	**	-465	**	-489	**
Ex. R&D	-1,822		-8,813		18,968		-1,586		-24,873	
Ih. R&D	15,325	**	17,227	**			13,676	*	19,092	**
Sci. staff					7,165					
Unionisation	15,468	***	16,009	***	15,844	***	12,727	***	10,699	**
Constant	63,374	***	60,233	***	63,579	***	71,298	***	75,196	***
Observations	66,470		66,470		66,470		66,470		60,989	
R-Square	.0124		.0123		.0123		.0126		.0096	
Firm FE	Yes		Yes		Yes		Yes		Yes	
Time FE	Yes		Yes		Yes		Yes		Yes	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table C.12: Robustness checks for stage 3

D. The Effects of Fragmentation on Employment and Productivity

D.1. More Information on Exiting Plants

In which sectors and regions did most of the exiting vertically integrated local units appear? There are significant differences between the tradable service sector and manufacturing. Table D.1 shows in the first column the total number of local units and in the second column the number of closed local units. In the third column we can find the share of closed local units to total number of local units in this industry and in the last column the proportion of closed local units of this industry to total number of closed local units. In manufacturing, most of the fragmentation happened for retail outlets, followed by different manufacturing industries. This is a surprising result, because we look at the closure of forward vertically integrated local units and we would expect retail outlets being downstream local units. A look at the input-output table reveals that a small but positive amount of goods from SIC 52 are used as intermediaries in manufacturing sectors. Therefore we will keep those observations. Nearly six percent of all closed local units have conducted business activities. In the tradable service sector three-fourth of all fragmented local units are from SIC 74 (other business activities) followed by SIC 72 (Computer and Related Activities). 86 percent of closed local units are covered by the top 5 industries.

Differences between the manufacturing and the tradable service sector also appear in the regional distribution of plant closures (see table D.2). 20 percent of all closed local units of service firms were located in London, followed by South East and South West. In manufacturing, fragmentation is more equally distributed over the whole country. Most closed local units of manufacturing firms are from the South West, followed by the North West and the West Midlands.

		Manufacturing			
SIC	Total no of Plants	Exiting Plants	Firm	Ind. Share	Total Share
52	15,465	952	513	6.16	11.46
22	28,053	680	416	2.42	8.19
15	26,390	658	355	2.49	7.92
28	27,773	652	541	2.35	7.85
29	20,396	616	473	3.02	7.42
74	5,270	546	491	10.36	6.57
		Tradable Services			
74	260,334	6,870	1,293	2.64	72.04
72	32,345	934	371	2.89	9.79
85	1,249	175	54	14.01	1.83
45	952	141	96	14.81	1.48
70	1,592	115	85	7.22	1.21

Notes:
15 Manufacturing of Food products, Beverages and Tobacco
22 Publishing, Printing and Reproduction of Recorded Media
25 Manufacture of Rubber and Plastic Products
28 Manufacture of Fabricated Metal Products, Except Machinery and Equipment
29 Manufacture of Machinery and Equipment Not Elsewhere Classified
45 Construction
52 Retail, Except of Motor veh. & motorc.; Repair of personal & household goods
70 Real Estate, Renting and Business Activities
72 Computer and Related Activities
74 Other Business Activities
85 Health and Social Work

Table D.1: Number of exiting local units per 2 digit SIC code for period 1998 – 2008.

Manufacturing					
GOR	Total no of Plants	Exiting Plants	firms	Ind. Share	Total Share
J	32,354	1,057	821	3.27	12.73
B	31,040	972	737	3.13	11.70
F	29,058	880	660	3.03	10.59
G	24,506	804	605	3.28	9.68
H	21,886	771	554	3.52	9.28
D	27,133	763	564	2.81	9.19
K	22,558	714	529	3.17	8.60
X	23,105	695	505	3.01	8.37
E	22,711	686	524	3.02	8.26
Tradable Services					
H	53,763	1,868	630	3.47	19.5
J	48,762	1,675	531	3.44	17.5
K	26,786	1,147	269	4.28	12.0
B	32,567	874	311	2.68	9.16
F	22,698	743	253	3.27	7.79
X	31,684	713	287	2.25	7.48
G	26,110	698	287	2.67	7.32
D	22,022	623	248	2.83	6.53
E	15,675	515	195	3.29	5.40

Notes:
B North West
D Yorkshire and The Humber
E East Midlands
F West Midlands
G East England
H London
J South East
K South West
X Scotland

Table D.2: Number of exiting local units per government office region for period 1998 – 2008.

D.2. More Information on Descriptive Statistics

Table D.3 presents descriptive statistics for the tradable service sector, if the outlier has not been dropped.

		Tradable Services			
t^*	Obs.	Employment	Net Emp.	R. Turn.	R. Firm Prod.
-2	64	38.88	33.42	3,014	85.96
-1	64	35.89	30.00	3,091	79.74
0	64	36.06	30.34	2,830	88.28
1	64	33.22	33.22	2,729	89.00
2	64	33.45	33.45	2,737	81.52
3	64	34.98	34.98	2,871	95.31
t^*	No. of Plants	Foreign	Concent.	Unionisation	Ih. R&D
-2	2.33	0.12	0.07	0.26	5.57
-1	2.33	0.09	0.06	0.24	5.67
0	2.33	0.06	0.06	0.20	5.69
1	1.33	0.07	0.07	0.19	4.18
2	1.33	0.06	0.07	0.17	6.27
3	1.33	0.06	0.07	0.16	0.56

Table D.3: Descriptive statistics of treatment group with outlier.

In the following tables we show descriptive statistics for the unbalanced samples.

					Manufacturing					
t^*	Obs.	Employment	Net Emp.	R. Turn.	R. Firm Prod.	No. of Plants	Foreign	Concent.	Unionisation	Ih. R&D
Treatment Group										
-2	310	179.85	146.91	15,337	74.85	3.09	0.25	0.10	0.46	0.02
-1	310	179.54	148.76	15,727	76.24	3.09	0.23	0.10	0.46	0.02
0	310	176.91	148.93	15,546	78.09	3.09	0.19	0.11	0.44	0.02
1	310	157.72	157.72	15,311	107.26	2.26	0.17	0.11	0.43	0.03
2	310	153.11	153.11	14,862	99.17	2.15	0.17	0.12	0.41	0.02
3	310	145.66	145.66	14,568	90.61	2.07	0.16	0.13	0.41	0.02
4	310	146.24	146.24	13,683	84.73	2.12	0.18	0.12	0.40	0.02
5	310	137.51	137.51	13,214	89.60	1.94	0.20	0.13	0.39	0.03
VI Control Group										
-2	5,840	78.86	78.86	8,496	85.15	1.84	0.10	0.10	0.45	0.03
-1	5,840	79.81	79.81	8,586	83.78	1.84	0.11	0.10	0.44	0.03
0	5,840	81.04	81.04	8,721	81.28	1.84	0.11	0.10	0.43	0.03
1	5,840	83.96	83.96	8,640	78.44	1.90	0.10	0.11	0.42	0.03
2	5,840	86.63	86.63	9,072	76.80	1.97	0.10	0.11	0.40	0.03
3	5,840	88.79	88.79	9,668	76.43	2.04	0.09	0.11	0.38	0.03
4	5,840	90.43	90.43	10,469	76.02	2.13	0.09	0.11	0.37	0.03
5	5,840	92.12	92.12	10,687	74.77	2.22	0.09	0.12	0.35	0.03
ALL Comparison Group										
-2	14,189	68.21	68.21	7,017	90.56	1.72	0.09	0.09	0.45	0.03
-1	14,189	69.28	69.28	7,117	89.66	1.72	0.10	0.10	0.44	0.03
0	14,189	70.29	70.29	7,195	88.12	1.72	0.10	0.10	0.43	0.03
1	14,189	72.89	72.89	7,254	84.43	1.80	0.09	0.10	0.41	0.03
2	14,189	74.35	74.35	7,573	82.79	1.85	0.09	0.11	0.39	0.04
3	14,189	75.05	75.05	7,897	83.17	1.88	0.08	0.11	0.38	0.04
4	14,189	75.65	75.65	8,266	84.39	1.92	0.09	0.11	0.36	0.04
5	14,189	76.25	76.25	8,408	82.44	1.95	0.09	0.11	0.34	0.04

Table D.4: Descriptive statistics for control and treatment groups in the manufacturing sector using the unrestricted balanced sample

					Manufacturing					
t^*	Obs.	Employment	Net Emp.	R. Turn.	R. Firm Prod.	No. of Plants	Foreign	Concent.	Unionisation	Ih. R&D
Treatment Group										
-3	367	89.83	75.11	8,201	63.74	2.23	0.13	0.21	0.44	0.35
-2	423	94.62	78.20	8,048	63.77	2.27	0.09	0.22	0.44	0.40
-1	423	89.08	74.19	7,709	66.56	2.27	0.08	0.22	0.42	0.32
0	423	84.45	70.63	7,657	64.91	2.27	0.07	0.24	0.40	0.35
1	423	70.82	70.82	6,967	80.10	1.27	0.07	0.25	0.39	1.07
2	366	63.04	63.04	6,205	79.61	1.25	0.06	0.26	0.37	0.43
3	319	64.33	64.33	6,390	78.88	1.23	0.07	0.27	0.37	0.42
4	221	55.46	55.46	4,875	74.29	1.23	0.08	0.25	0.37	0.49
5	165	59.56	59.56	5,636	78.96	1.26	0.12	0.26	0.38	0.37
6	105	57.26	57.26	5,559	76.29	1.30	0.10	0.28	0.38	0.41
VI Control Group										
-3	5,211	53.49	53.49	4,737	63.45	2.25	0.11	0.22	0.44	0.35
-2	6,284	54.55	54.55	4,832	63.46	2.26	0.10	0.22	0.43	0.37
-1	6,284	54.19	54.19	4,866	63.41	2.26	0.09	0.23	0.41	0.41
0	6,284	53.75	53.75	4,873	63.26	2.26	0.08	0.23	0.40	0.46
1	6,284	52.96	52.96	4,867	63.30	2.26	0.08	0.24	0.38	0.50
2	5,211	51.45	51.45	4,793	63.39	2.25	0.07	0.24	0.37	0.52
3	4,245	50.74	50.74	4,819	63.95	2.24	0.06	0.24	0.36	0.54
4	3,382	50.57	50.57	4,924	65.00	2.23	0.06	0.25	0.35	0.54
5	2,591	50.16	50.16	5,040	66.09	2.23	0.06	0.26	0.33	0.55
6	1,871	50.01	50.01	5,141	67.73	2.23	0.06	0.26	0.33	0.55
ALL Comparison Group										
-3	10,261	48.26	48.26	4,416	68.35	2.17	0.10	0.22	0.43	0.34
-2	12,447	49.49	49.49	4,487	68.01	2.18	0.09	0.22	0.43	0.35
-1	12,447	49.10	49.10	4,497	67.78	2.18	0.08	0.23	0.41	0.40
0	12,447	48.72	48.72	4,479	67.09	2.18	0.08	0.23	0.40	0.46
1	12,447	47.94	47.94	4,446	66.95	2.18	0.07	0.24	0.38	0.49
2	10,261	46.15	46.15	4,345	67.10	2.17	0.06	0.24	0.37	0.53
3	8,319	44.70	44.70	4,300	67.85	2.17	0.06	0.25	0.36	0.54
4	6,615	44.17	44.17	4,315	68.80	2.16	0.06	0.25	0.35	0.54
5	5,073	43.56	43.56	4,343	69.44	2.16	0.06	0.26	0.34	0.56
6	3,665	43.36	43.36	4,426	70.71	2.16	0.06	0.27	0.33	0.56

Table D.5: Descriptive statistics for control and treatment groups in the manufacturing sector using the restricted unbalanced sample

					Manufacturing					
t*	Obs.	Employment	Net Emp.	R. Turn.	R. Firm Prod.	No. of Plants	Foreign	Concent.	Unionisation	Ih. R&D
Treatment Group										
-3	549	108.75	90.17	9,852	68.12	2.58	0.16	0.10	0.44	0.05
-2	680	145.12	120.46	12,347	69.94	2.81	0.14	0.11	0.44	0.03
-1	680	141.85	118.89	12,131	71.80	2.81	0.13	0.11	0.43	0.02
0	680	137.14	115.63	12,090	71.12	2.81	0.13	0.12	0.41	0.03
1	680	121.26	121.26	11,586	90.20	1.96	0.12	0.12	0.40	0.03
2	595	117.10	117.10	11,398	90.51	1.91	0.12	0.12	0.39	0.03
3	525	117.21	117.21	11,700	84.14	1.92	0.12	0.13	0.38	0.03
4	385	130.32	130.32	11,757	81.12	2.10	0.16	0.12	0.39	0.03
5	296	134.57	134.57	12,727	88.41	1.93	0.20	0.13	0.39	0.03
6	205	158.43	158.43	18,493	91.16	2.10	0.22	0.13	0.40	0.02
VI Control Group										
-3	9,493	76.92	76.92	8,037	80.76	1.94	0.10	0.10	0.44	0.03
-2	11,668	79.30	79.30	8,422	80.33	1.94	0.10	0.10	0.43	0.03
-1	11,668	79.54	79.54	8,549	79.32	1.94	0.10	0.10	0.42	0.03
0	11,668	80.43	80.43	8,763	78.12	1.94	0.10	0.11	0.40	0.03
1	11,668	83.42	83.42	8,955	75.60	2.03	0.10	0.11	0.39	0.03
2	10,117	86.16	86.16	9,187	74.33	2.08	0.10	0.11	0.38	0.03
3	8,601	87.89	87.89	9,652	74.36	2.12	0.09	0.11	0.37	0.03
4	7,136	89.46	89.46	10,211	74.14	2.17	0.09	0.11	0.36	0.03
5	5,691	90.40	90.40	10,370	73.92	2.22	0.09	0.12	0.35	0.03
6	4,236	92.86	92.86	10,650	73.85	2.28	0.09	0.12	0.35	0.03
ALL Comparison Group										
-3	22,788	68.16	68.16	6,999	88.78	1.77	0.09	0.10	0.44	0.03
-2	28,326	69.36	69.36	7,142	88.96	1.77	0.09	0.10	0.43	0.03
-1	28,326	69.71	69.71	7,230	87.71	1.77	0.09	0.10	0.42	0.03
0	28,326	70.30	70.30	7,344	86.30	1.77	0.09	0.10	0.40	0.04
1	28,326	72.60	72.60	7,521	83.28	1.87	0.09	0.11	0.39	0.04
2	24,237	73.92	73.92	7,671	82.11	1.91	0.09	0.11	0.38	0.04
3	20,477	74.01	74.01	7,818	82.82	1.93	0.08	0.11	0.37	0.04
4	16,999	74.60	74.60	8,069	81.17	1.95	0.09	0.11	0.36	0.04
5	13,604	75.35	75.35	8,245	80.37	1.96	0.09	0.11	0.34	0.04
6	10,220	76.91	76.91	8,513	80.70	1.98	0.09	0.11	0.34	0.03

Table D.6: Descriptive statistics for control and treatment groups in the manufacturing sector using the unrestricted unbalanced sample

					Tradable Services					
t^*	Obs.	Employment	Net Emp.	R. Turn.	R. Firm Prod.	No. of Plants	Foreign	Concent.	Unionisation	Ih. R&D
Treatment Group										
-2	134	64.03	55.53	4,708	126.73	2.84	0.14	0.05	0.26	0.10
-1	134	64.59	55.71	4,734	138.34	2.84	0.10	0.04	0.25	0.09
0	134	65.97	57.28	4,323	115.51	2.84	0.09	0.04	0.22	0.11
1	134	64.61	64.61	5,011	99.94	2.01	0.09	0.03	0.19	0.10
2	134	67.38	67.38	4,507	84.07	1.93	0.09	0.04	0.17	0.10
3	134	68.35	68.35	4,692	92.27	1.88	0.10	0.04	0.16	0.07
VI Control Group										
-2	3,897	25.32	25.32	2,540	116.45	1.79	0.07	0.04	0.29	0.19
-1	3,897	26.98	26.98	2,778	116.08	1.79	0.07	0.04	0.27	0.17
0	3,897	28.91	28.91	2,971	114.67	1.79	0.07	0.04	0.24	0.18
1	3,897	32.20	32.20	3,246	117.93	1.88	0.07	0.04	0.22	0.18
2	3,897	36.96	36.96	3,394	96.20	2.01	0.06	0.04	0.20	0.21
3	3,897	41.16	41.16	3,697	93.83	2.15	0.06	0.04	0.19	0.22
ALL comparison Group										
-2	27,134	31.16	31.16	2,210	90.27	1.87	0.04	0.04	0.26	0.06
-1	27,134	32.80	32.80	2,414	90.24	1.87	0.04	0.04	0.24	0.06
0	27,134	34.56	34.56	2,524	86.32	1.87	0.04	0.04	0.21	0.06
1	27,134	37.74	37.74	2,701	82.07	1.95	0.04	0.04	0.19	0.06
2	27,134	40.88	40.88	2,817	74.43	2.01	0.03	0.04	0.17	0.07
3	27,134	43.16	43.16	2,937	73.90	2.07	0.03	0.04	0.15	0.07

Table D.7: Descriptive statistics for control and treatment groups in the tradable service sector using the unrestricted balanced sample

					Tradable Services					
t*	Obs.	Employment	Net Emp.	R. Turn.	R. Firm Prod.	No. of Plants	Foreign	Concent.	Unionisation	Ih. R&D
Treatment Group										
-3	82	31.79	26.59	1,935	131.52	2.34	0.08	0.08	0.26	0.35
-2	94	39.30	33.21	3,028	86.05	2.32	0.10	0.08	0.25	4.00
-1	94	39.12	32.80	3,701	99.39	2.32	0.10	0.07	0.23	4.05
0	94	38.61	32.39	3,563	103.34	2.32	0.08	0.07	0.20	4.28
1	94	31.24	31.24	2,914	99.21	1.32	0.07	0.07	0.18	3.38
2	81	32.15	32.15	2,731	82.74	1.27	0.05	0.07	0.16	5.06
3	64	34.98	34.98	2,871	95.31	1.33	0.06	0.07	0.16	0.56
4	40	40.00	40.00	6,536	264.06	1.33	0.08	0.10	0.16	0.52
5	24	50.54	50.54	5,974	176.24	1.25	0.13	0.11	0.13	0.72
6	16	61.00	61.00	8,311	247.02	1.19	0.06	0.09	0.13	0.73
VI Control Group										
-3	2,160	12.61	12.61	842	66.65	2.18	0.07	0.10	0.29	2.16
-2	2,637	13.31	13.31	882	66.51	2.20	0.06	0.10	0.28	2.77
-1	2,637	13.27	13.27	890	66.33	2.20	0.06	0.10	0.26	3.60
0	2,637	13.30	13.30	879	66.35	2.20	0.05	0.10	0.23	4.79
1	2,637	13.22	13.22	866	66.69	2.20	0.05	0.10	0.21	5.59
2	2,160	12.43	12.43	828	68.12	2.18	0.04	0.10	0.20	6.52
3	1,737	12.13	12.13	822	69.40	2.16	0.04	0.10	0.19	7.56
4	1,376	11.96	11.96	830	70.11	2.17	0.04	0.10	0.18	7.15
5	1,051	12.04	12.04	852	71.27	2.17	0.04	0.10	0.15	6.70
6	755	12.18	12.18	889	73.20	2.17	0.04	0.10	0.15	5.96
ALL Comparison Group										
-3	12,447	18.64	18.64	925	59.26	2.19	0.03	0.06	0.25	0.92
-2	14,959	18.97	18.97	971	59.97	2.19	0.03	0.06	0.24	1.19
-1	14,959	19.19	19.19	1,002	60.38	2.19	0.02	0.06	0.22	1.53
0	14,959	19.39	19.39	1,009	60.00	2.19	0.02	0.06	0.19	2.00
1	14,959	19.53	19.53	1,021	59.64	2.19	0.02	0.06	0.17	2.33
2	12,447	19.39	19.39	989	58.82	2.19	0.02	0.06	0.16	2.69
3	10,181	19.46	19.46	981	58.01	2.18	0.01	0.06	0.15	3.09
4	8,151	19.69	19.69	986	57.07	2.18	0.01	0.06	0.14	2.93
5	6,295	19.92	19.92	996	56.75	2.18	0.01	0.06	0.12	2.75
6	4,572	20.20	20.20	990	56.26	2.19	0.01	0.06	0.12	2.43

Table D.8: Descriptive statistics for control and treatment groups in the tradable service sector using the restricted unbalanced sample

					Tradable Services					
t^*	Obs.	Employment	Net Emp.	R. Turn.	R. Firm Prod.	No. of Plants	Foreign	Concent.	Unionisation	Ih. R&D
Treatment Group										
-3	153	44.49	36.56	2,925	151.11	2.54	0.09	0.04	0.26	0.07
-2	174	60.61	51.65	4,058	116.32	2.55	0.11	0.04	0.25	0.08
-1	174	61.80	52.52	4,538	127.69	2.55	0.10	0.04	0.24	0.07
0	174	62.93	53.55	4,419	121.89	2.55	0.09	0.04	0.21	0.09
1	174	56.84	56.84	4,259	104.50	1.72	0.07	0.04	0.19	0.11
2	147	58.03	58.03	3,833	84.43	1.78	0.05	0.04	0.17	0.11
3	117	58.89	58.89	3,749	87.25	1.72	0.09	0.04	0.16	0.07
4	77	73.55	73.55	5,926	168.94	1.87	0.08	0.04	0.16	0.06
5	50	90.82	90.82	6,067	123.67	1.92	0.10	0.03	0.14	0.05
6	35	114.14	114.14	8,551	151.52	1.83	0.09	0.04	0.14	0.04
VI Control Group										
-3	4,099	24.44	24.44	2,283	108.68	1.88	0.07	0.04	0.28	0.19
-2	5,127	25.44	25.44	2,511	109.21	1.87	0.07	0.04	0.28	0.20
-1	5,127	26.96	26.96	2,819	120.25	1.87	0.07	0.04	0.25	0.19
0	5,127	29.87	29.87	2,962	117.47	1.87	0.07	0.04	0.23	0.17
1	5,127	34.07	34.07	3,008	100.78	1.97	0.07	0.04	0.21	0.17
2	4,411	37.44	37.44	3,289	94.39	2.04	0.06	0.04	0.20	0.21
3	3,722	39.40	39.40	3,570	93.63	2.13	0.06	0.04	0.19	0.22
4	3,065	41.92	41.92	3,710	89.12	2.25	0.07	0.04	0.18	0.23
5	2,419	45.52	45.52	4,161	109.45	2.35	0.07	0.04	0.15	0.24
6	1,793	50.34	50.34	4,277	110.96	2.43	0.08	0.04	0.15	0.15
ALL Comparison Group										
-3	27,955	29.51	29.51	2,115	82.61	1.88	0.03	0.04	0.25	0.07
-2	35,215	30.24	30.24	2,169	85.56	1.86	0.03	0.04	0.24	0.07
-1	35,215	31.81	31.81	2,320	86.55	1.86	0.03	0.04	0.22	0.07
0	35,215	33.60	33.60	2,427	83.12	1.86	0.03	0.04	0.20	0.06
1	35,215	36.49	36.49	2,536	76.53	1.97	0.03	0.04	0.18	0.07
2	30,051	39.63	39.63	2,698	73.72	2.02	0.03	0.04	0.17	0.07
3	25,507	41.75	41.75	2,824	73.32	2.08	0.03	0.04	0.16	0.08
4	21,311	44.25	44.25	2,884	73.56	2.12	0.03	0.04	0.14	0.08
5	17,105	47.33	47.33	3,024	74.68	2.15	0.03	0.04	0.12	0.08
6	12,900	50.83	50.83	3,194	72.54	2.18	0.04	0.04	0.12	0.07

Table D.9: Descriptive statistics for control and treatment groups in the tradable service sector using the unrestricted unbalanced sample

D.3. More Information on Regression Results

In this section we present regression results using the unbalanced samples.

Variables	Restricted VI		Restricted All		Unrestr. VI		Unrestr. All	
t^*_{-2}	-0.005	***	-0.006	***	0.009	***	0.006	***
	(0.002)		(0.001)		(0.002)		(0.001)	
t^*_{-1}	-0.011	***	-0.011	***	0.024	***	0.024	***
	(0.003)		(0.002)		(0.004)		(0.002)	
t^*_0	-0.018	***	-0.017	***	0.041	***	0.043	***
	(0.004)		(0.003)		(0.005)		(0.004)	
t^*_1	-0.026	***	-0.024	***	0.077	***	0.078	***
	(0.006)		(0.004)		(0.007)		(0.005)	
t^*_2	-0.033	***	-0.032	***	0.111	***	0.106	***
	(0.007)		(0.005)		(0.010)		(0.006)	
t^*_3	-0.041	***	-0.041	***	0.134	***	0.119	***
	(0.009)		(0.006)		(0.012)		(0.008)	
t^*_4	-0.050	***	-0.050	***	0.155	***	0.129	***
	(0.011)		(0.007)		(0.014)		(0.009)	
t^*_5	-0.058	***	-0.058	***	0.175	***	0.138	***
	(0.013)		(0.009)		(0.016)		(0.010)	
t^*_6	-0.064	***	-0.064	***	0.197	***	0.149	***
	(0.015)		(0.010)		(0.018)		(0.012)	
$\text{frag}_i \times t^*_{-1}$	-0.006		-0.006		-0.027	***	-0.029	***
	(0.008)		(0.008)		(0.007)		(0.006)	
$\text{frag}_i \times t^*_0$	-0.009		-0.011		-0.054	***	-0.057	***
	(0.009)		(0.009)		(0.008)		(0.008)	
$\text{frag}_i \times t^*_1$	-0.285	***	-0.287	***	-0.321	***	-0.325	***
	(0.028)		(0.028)		(0.022)		(0.022)	
$\text{frag}_i \times t^*_2$	-0.278	***	-0.279	***	-0.359	***	-0.355	***
	(0.030)		(0.030)		(0.024)		(0.023)	
$\text{frag}_i \times t^*_3$	-0.278	***	-0.279	***	-0.396	***	-0.384	***
	(0.031)		(0.031)		(0.026)		(0.025)	
$\text{frag}_i \times t^*_4$	-0.299	***	-0.300	***	-0.431	***	-0.407	***
	(0.034)		(0.034)		(0.030)		(0.029)	
$\text{frag}_i \times t^*_5$	-0.333	***	-0.333	***	-0.507	***	-0.472	***
	(0.039)		(0.038)		(0.036)		(0.034)	
$\text{frag}_i \times t^*_6$	-0.346	***	-0.346	***	-0.566	***	-0.519	***
	(0.047)		(0.045)		(0.042)		(0.040)	
Constant	3.038	***	2.893	***	3.368	***	3.225	***
	(0.005)		(0.004)		(0.007)		(0.004)	
Fixed effects	Yes		Yes		Yes		Yes	
Observations	50,882		97,217		97,221		226,881	
R-Square	.0744		.0532		.0511		.0301	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table D.10: Regression results for total employment effects in manufacturing using unbalanced restricted and unrestricted samples

Variables	Restricted VI		Restricted All		Unrestr. VI		Unrestr. All	
t^*_{-2}	-0.005	**	-0.006	***	0.010	***	0.006	***
	(0.002)		(0.001)		(0.002)		(0.001)	
t^*_{-1}	-0.011	***	-0.011	***	0.025	***	0.024	***
	(0.003)		(0.002)		(0.004)		(0.002)	
t^*_0	-0.018	***	-0.017	***	0.042	***	0.043	***
	(0.004)		(0.003)		(0.005)		(0.004)	
t^*_1	-0.025	***	-0.024	***	0.077	***	0.078	***
	(0.006)		(0.004)		(0.007)		(0.005)	
t^*_2	-0.033	***	-0.032	***	0.111	***	0.106	***
	(0.007)		(0.005)		(0.010)		(0.006)	
t^*_3	-0.041	***	-0.041	***	0.134	***	0.119	***
	(0.009)		(0.006)		(0.012)		(0.008)	
t^*_4	-0.050	***	-0.050	***	0.155	***	0.129	***
	(0.011)		(0.007)		(0.014)		(0.009)	
t^*_5	-0.058	***	-0.058	***	0.175	***	0.139	***
	(0.013)		(0.009)		(0.016)		(0.010)	
t^*_6	-0.063	***	-0.064	***	0.197	***	0.149	***
	(0.015)		(0.010)		(0.018)		(0.012)	
$frag_i \times t^*_{-1}$	0.002		0.001		-0.020	**	-0.022	**
	(0.009)		(0.009)		(0.008)		(0.007)	
$frag_i \times t^*_0$	-0.003		-0.004		-0.044	***	-0.048	***
	(0.011)		(0.011)		(0.009)		(0.009)	
$frag_i \times t^*_1$	0.105	***	0.103	***	0.033		0.030	
	(0.031)		(0.031)		(0.025)		(0.024)	
$frag_i \times t^*_2$	0.105	**	0.104	**	-0.017		-0.013	
	(0.034)		(0.034)		(0.028)		(0.027)	
$frag_i \times t^*_3$	0.111	**	0.110	**	-0.053		-0.041	
	(0.037)		(0.036)		(0.031)		(0.030)	
$frag_i \times t^*_4$	0.091	*	0.091	*	-0.100	**	-0.076	*
	(0.041)		(0.041)		(0.035)		(0.033)	
$frag_i \times t^*_5$	0.056		0.056		-0.180	***	-0.145	***
	(0.046)		(0.045)		(0.039)		(0.038)	
$frag_i \times t^*_6$	0.052		0.052		-0.239	***	-0.192	***
	(0.054)		(0.053)		(0.045)		(0.043)	
Constant	3.013	***	2.880	***	3.349	***	3.217	***
	(0.005)		(0.004)		(0.007)		(0.004)	
Fixed effects	Yes		Yes		Yes		Yes	
Observations	50,879		97,214		97,216		226,876	
R-Square	.0153		.0162		.0406		.0259	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table D.11: Regression results for indirect employment effects in manufacturing using unbalanced restricted and unrestricted samples

Variables	**Balanced VI**		**Balanced All**		**Unbalan. VI**		**Unbalan. All**	
t^*_{-2}	0.011	**	0.011	***	0.012	***	0.013	***
	(0.003)		(0.003)		(0.003)		(0.002)	
t^*_{-1}	0.027	***	0.022	***	0.029	***	0.025	***
	(0.006)		(0.004)		(0.005)		(0.003)	
t^*_{0}	0.029	**	0.022	***	0.034	***	0.027	***
	(0.009)		(0.007)		(0.007)		(0.005)	
t^*_{1}	0.030	*	0.024	**	0.024	**	0.016	**
	(0.012)		(0.009)		(0.009)		(0.006)	
t^*_{2}	0.039	*	0.034	**	0.024	*	0.023	**
	(0.015)		(0.011)		(0.011)		(0.007)	
t^*_{3}	0.046	*	0.044	**	0.037	**	0.041	***
	(0.019)		(0.014)		(0.013)		(0.008)	
t^*_{4}	0.055	*	0.056	***	0.045	**	0.058	***
	(0.023)		(0.016)		(0.015)		(0.010)	
t^*_{5}	0.068	*	0.071	***	0.057	***	0.077	***
	(0.026)		(0.019)		(0.017)		(0.011)	
t^*_{6}	0.087	**	0.095	***	0.074	***	0.101	***
	(0.030)		(0.021)		(0.019)		(0.012)	
$frag_i \times t^*_{-1}$	-0.000		0.005		0.009		0.013	
	(0.019)		(0.018)		(0.019)		(0.019)	
$frag_i \times t^*_{0}$	0.011		0.017		0.020		0.027	
	(0.021)		(0.020)		(0.019)		(0.018)	
$frag_i \times t^*_{1}$	0.246	***	0.252	***	0.227	***	0.235	***
	(0.031)		(0.030)		(0.024)		(0.023)	
$frag_i \times t^*_{2}$	0.210	***	0.216	***	0.217	***	0.218	***
	(0.036)		(0.034)		(0.028)		(0.027)	
$frag_i \times t^*_{3}$	0.236	***	0.238	***	0.235	***	0.231	***
	(0.037)		(0.035)		(0.029)		(0.027)	
$frag_i \times t^*_{4}$	0.220	***	0.219	***	0.204	***	0.192	***
	(0.038)		(0.035)		(0.032)		(0.030)	
$frag_i \times t^*_{5}$	0.257	***	0.253	***	0.255	***	0.235	***
	(0.051)		(0.048)		(0.039)		(0.037)	
$frag_i \times t^*_{6}$	0.248	***	0.240	***	0.288	***	0.262	***
	(0.065)		(0.062)		(0.045)		(0.042)	
Constant	3.836	***	3.876	***	4.036	***	4.080	***
	(0.011)		(0.008)		(0.008)		(0.005)	
Fixed effects	Yes		Yes		Yes		Yes	
Observations	50,808		96,952		97,068		226,444	
R-Square	.0109		.00734		.00727		.00565	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table D.12: Regression results for firm average labour productivity effects in manufacturing using unbalanced restricted and unrestricted samples

Variables	Balanced VI		Balanced All		Unbalan. VI		Unbalan. All	
t^*_{-2}	-0.003		0.003	**	0.016	**	0.018	***
	(0.002)		(0.001)		(0.005)		(0.002)	
t^*_{-1}	-0.007	*	0.007	***	0.065	***	0.063	***
	(0.003)		(0.002)		(0.008)		(0.003)	
t^*_0	-0.012	*	0.009	***	0.119	***	0.111	***
	(0.005)		(0.003)		(0.012)		(0.004)	
t^*_1	-0.015	*	0.011	***	0.195	***	0.172	***
	(0.006)		(0.003)		(0.017)		(0.005)	
t^*_2	-0.019	*	0.013	**	0.289	***	0.231	***
	(0.007)		(0.004)		(0.022)		(0.007)	
t^*_3	-0.024	**	0.016	**	0.346	***	0.265	***
	(0.009)		(0.005)		(0.025)		(0.009)	
t^*_4	-0.030	**	0.019	**	0.395	***	0.292	***
	(0.011)		(0.006)		(0.029)		(0.010)	
t^*_5	-0.035	**	0.022	**	0.450	***	0.323	***
	(0.013)		(0.007)		(0.032)		(0.012)	
t^*_6	-0.040	**	0.024	**	0.499	***	0.355	***
	(0.015)		(0.008)		(0.036)		(0.013)	
$frag_i \times t^*_{-1}$	0.043	*	0.032		-0.034	*	-0.031	*
	(0.021)		(0.021)		(0.016)		(0.015)	
$frag_i \times t^*_0$	0.053	*	0.036		-0.044		-0.036	
	(0.021)		(0.021)		(0.023)		(0.021)	
$frag_i \times t^*_1$	-0.210	***	-0.233	***	-0.285	***	-0.260	***
	(0.063)		(0.062)		(0.054)		(0.052)	
$frag_i \times t^*_2$	-0.204	**	-0.233	**	-0.361	***	-0.303	***
	(0.071)		(0.071)		(0.063)		(0.060)	
$frag_i \times t^*_3$	-0.202	**	-0.239	**	-0.405	***	-0.323	***
	(0.077)		(0.077)		(0.076)		(0.073)	
$frag_i \times t^*_4$	-0.246	**	-0.291	***	-0.480	***	-0.376	***
	(0.079)		(0.078)		(0.081)		(0.077)	
$frag_i \times t^*_5$	-0.277	**	-0.330	***	-0.544	***	-0.417	***
	(0.097)		(0.096)		(0.102)		(0.098)	
$frag_i \times t^*_6$	-0.291	**	-0.352	***	-0.594	***	-0.449	***
	(0.096)		(0.095)		(0.125)		(0.121)	
Constant	1.960	***	2.318	***	2.283	***	2.501	***
	(0.006)		(0.003)		(0.015)		(0.005)	
Fixed effects	Yes		Yes		Yes		Yes	
Observations	20,470		114,612		41,287		276,880	
R-Square	.0457		.00798		.115		.0695	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table D.13: Regression results for total employment effects in tradable service sector using unbalanced restricted and unrestricted samples

Variables	Balanced VI		Balanced All		Unbalan. VI		Unbalan. All	
t^*_{-2}	-0.003		0.003	**	0.017	**	0.018	***
	(0.002)		(0.001)		(0.005)		(0.002)	
t^*_{-1}	-0.007	*	0.007	***	0.065	***	0.063	***
	(0.003)		(0.002)		(0.008)		(0.003)	
t^*_0	-0.012	*	0.009	***	0.119	***	0.111	***
	(0.005)		(0.003)		(0.012)		(0.004)	
t^*_1	-0.015	*	0.011	***	0.196	***	0.172	***
	(0.006)		(0.003)		(0.017)		(0.005)	
t^*_2	-0.019	*	0.013	**	0.289	***	0.231	***
	(0.007)		(0.004)		(0.022)		(0.007)	
t^*_3	-0.024	**	0.016	**	0.347	***	0.265	***
	(0.009)		(0.005)		(0.025)		(0.009)	
t^*_4	-0.030	**	0.019	**	0.395	***	0.292	***
	(0.011)		(0.006)		(0.029)		(0.010)	
t^*_5	-0.035	**	0.021	**	0.450	***	0.323	***
	(0.013)		(0.007)		(0.032)		(0.012)	
t^*_6	-0.040	**	0.024	**	0.500	***	0.355	***
	(0.015)		(0.008)		(0.036)		(0.013)	
$\text{frag}_i \times t^*_{-1}$	0.060		0.049		-0.013		-0.010	
	(0.037)		(0.037)		(0.025)		(0.024)	
$\text{frag}_i \times t^*_0$	0.074	*	0.056		-0.020		-0.012	
	(0.037)		(0.036)		(0.032)		(0.030)	
$\text{frag}_i \times t^*_1$	0.161	*	0.138	*	0.089		0.113	
	(0.070)		(0.070)		(0.066)		(0.064)	
$\text{frag}_i \times t^*_2$	0.180	*	0.150		0.020		0.079	
	(0.083)		(0.083)		(0.076)		(0.074)	
$\text{frag}_i \times t^*_3$	0.158		0.122		-0.029		0.053	
	(0.093)		(0.092)		(0.092)		(0.089)	
$\text{frag}_i \times t^*_4$	0.104		0.058		-0.104		0.001	
	(0.094)		(0.093)		(0.098)		(0.095)	
$\text{frag}_i \times t^*_5$	0.044		-0.009		-0.154		-0.027	
	(0.110)		(0.109)		(0.124)		(0.120)	
$\text{frag}_i \times t^*_6$	0.008		-0.053		-0.219		-0.074	
	(0.111)		(0.110)		(0.144)		(0.140)	
Constant	1.948	***	2.316	***	2.271	***	2.500	***
	(0.006)		(0.003)		(0.015)		(0.005)	
Fixed effects	Yes		Yes		Yes		Yes	
Observations	20,470		114,612		41,287		276,880	
R-Square	.0155		.00355		.116		.0697	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table D.14: Regression results for indirect employment effects in tradable service sector using unbalanced restricted and unrestricted samples

Variables	Balanced VI		Balanced All		Unbalan. VI		Unbalan. All	
t^*_{-2}	-0.004		0.018	***	0.002		0.016	***
	(0.008)		(0.003)		(0.007)		(0.002)	
t^*_{-1}	-0.002		0.037	***	0.006		0.032	***
	(0.015)		(0.005)		(0.012)		(0.004)	
t^*_0	-0.018		0.041	***	-0.009		0.034	***
	(0.021)		(0.007)		(0.016)		(0.005)	
t^*_1	-0.023		0.044	***	-0.040	*	0.019	**
	(0.025)		(0.010)		(0.020)		(0.007)	
t^*_2	-0.029		0.058	***	-0.076	**	0.024	**
	(0.032)		(0.013)		(0.024)		(0.008)	
t^*_3	-0.034		0.074	***	-0.077	**	0.044	***
	(0.038)		(0.016)		(0.028)		(0.010)	
t^*_4	-0.027		0.092	***	-0.078	*	0.067	***
	(0.044)		(0.019)		(0.031)		(0.011)	
t^*_5	-0.016		0.105	***	-0.077	*	0.084	***
	(0.050)		(0.022)		(0.035)		(0.012)	
t^*_6	0.007		0.127	***	-0.079	*	0.099	***
	(0.056)		(0.024)		(0.038)		(0.014)	
$frag_i \times t^*_{-1}$	0.008		-0.019		0.042		0.024	
	(0.051)		(0.050)		(0.034)		(0.033)	
$frag_i \times t^*_0$	0.041		-0.006		0.029		-0.007	
	(0.061)		(0.059)		(0.045)		(0.044)	
$frag_i \times t^*_1$	0.206	**	0.150	*	0.150	*	0.099	
	(0.077)		(0.075)		(0.060)		(0.057)	
$frag_i \times t^*_2$	0.212	**	0.138		0.106		0.014	
	(0.079)		(0.075)		(0.075)		(0.072)	
$frag_i \times t^*_3$	0.219	*	0.123		0.087		-0.027	
	(0.094)		(0.088)		(0.078)		(0.075)	
$frag_i \times t^*_4$	0.101		-0.006		0.155		0.017	
	(0.170)		(0.166)		(0.106)		(0.103)	
$frag_i \times t^*_5$	0.178		0.068		0.226		0.072	
	(0.178)		(0.172)		(0.116)		(0.112)	
$frag_i \times t^*_6$	0.083		-0.024		0.248		0.077	
	(0.262)		(0.257)		(0.163)		(0.160)	
Constant	3.635	***	3.545	***	3.968	***	3.754	***
	(0.022)		(0.009)		(0.017)		(0.006)	
Fixed effects	Yes		Yes		Yes		Yes	
Observations	20,378		114,233		41,088		276,102	
R-Square	.00141		.00455		.00383		.00226	

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table D.15: Regression results for firm average labour productivity effects in tradable service sector using unbalanced restricted and unrestricted samples